

56/1320

SHORT  
PRINCIPLES  
FOR THE  
ARCHITECTURE  
OF  
STONE-BRIDGES

WITH  
PRACTICAL OBSERVATIONS,  
AND A  
New Geometrical Diagram to determine the  
Thicknes of the PIERS to the Height  
and Base of any given ARCH.  
IN TWELVE SECTIONS.

Illustrated with FIGURES.

---

By STEPHEN RIOUS, Esq; Architect.

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*Edificare, diu cogitare oportet.*

CATO.

*Perpetuo liceat sic tibi ponte frui.*

MART.

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56

REPORT  
P. H. N. G. L. E. S.

ARCHITECTURE

STONE BRIDGE

PRACTICAL OBSERVATIONS

ON THE  
CONSTRUCTION OF  
THE BRIDGE

IN TWELVE SECTIONS

BY STEPHEN H. H. H. H.

OF THE  
OFFICE OF THE  
ENGINEER

OF THE  
STATE OF  
NEW YORK





*The SOCIETY for the  
Encouragement of ARTS,  
&c.*

S I R S,

**I***N taking the liberty to lay this  
little performance before you, I  
do it with the View to beg the pro-  
tection of your society, so wisely and  
generously established for the advance-  
ment of every art useful in civil life.*

*Tho' I enjoy the peculiar happiness  
to be born a subject of Britain, I*

#### iv DEDICATION.

*have at times roamed from the boundaries of this beautiful spot : in declaring that the motives of my excursions were not altogether discommendable, I only mean to lay claim to a small share of industry.*

*The first of my studies in architecture was at a foreign protestant academy of note, which has long been honoured by a successive residence of numbers of the young nobility of these kingdoms, and of the first rank.*

*A few years after, while Europe breathed a short peace, I took that opportunity to visit other countries ; but I soon hastened to Italy : it was there I did sit down with all the application I was capable of, and endeavoured*

## DEDICATION. 7

*deavoured to answer in some measure  
the chief purposes of my errand.*

*The subject I have chosen to handle  
is a branch of it, but a branch that  
seems to have been but little considered  
by the architects of this country. I  
understand that there is a design ir-  
refragably fixed upon and to be put  
in execution ; whether this design is  
without very exceptionable errors, is a  
question now too late to be considered.  
— Far be it from me to insinuate,  
that the Better or Worse has not been,  
as far as they were able, attended to  
by those who have the management  
of this great work. Nor can it be  
once imagined, that the least tinc-  
ture of partiality should affect any  
body of men at this glorious pe-  
riod,*



vi DEDICATION.

*riod, when the most important affairs  
are managed from the THRONE it-  
self, with unparaleted candor, pru-  
dence, and vigour; and that the  
world sees such an illustrious pat-  
tern of extensive munificence and be-  
nevolence in your respectable society.  
I am,*

SIRS,

Your most humble,

and most obedient, and

most devoted servant,

Hern-Hill near Feverham,  
9 April 1760.

STEPHEN RIOU,

## P R E F A C E.

**T**HE construction of bridges is an essential part of the architect's study, yet I know of no book in the *English* language that treats of it with the detail and method that it requires.

By detail, is to be understood all the practical observations and rules, which are to be deduced from experience, or from the writings and conversations of such artists who have been long employed in works of the same sort, and will honestly communicate their practice, ingenuously point out any errors they or their associates may have committed, and generously offer the most likely means of further improvement; for without all those helps, and the other considerations —

*In vitium ducit culpæ fuga si caret arte.*

HOR.

By method I mean all that relates to the design of any undertaking, and the several previous questions to be agitated. Herein the architect must have recourse to the several aids of geometry, mechanicks, &c. But I mean not that high geometry, which, by plunging into the depths of analytic reasoning oftentimes unfathomable, is on many occasions at a loss to determine the most common cases. — The subject before us by no means requires it; why need they have recourse to the quadrature of the circle, or of the ellipsis, for the calculation of the contents of arches, and to determine the resistances they require? — These will be found sufficiently exact, by considering the curvature of the arches as polygonal, and their vouffoirs as so many rectilinear inclined planes, in different directions according to which their powers and pressures are discoverable, and  
thence



## P R E F A C E.

ix

thence may be determined the requisite opposed strength of the piers, so that each arch may stand independent, without affecting, or being affected by any other.

How these ends are answered, by the rules I have selected, I leave to the judgment of others.—I must acquaint the reader, that I have suppressed, for brevity sake, and the time pressing, the tediousness of demonstrations, especially as the nature of the propositions will very sufficiently declare, to what part of geometry or mechanicks they may be referred, and treatises for these sciences are undoubtedly in every gentleman's possession.

M. *Gautier*, from a long experience in these sorts of fabricks, did compose a most useful \* treatise upon bridges; but the editor has not done justice to so valuable a work, by not having it properly digested for the press, or the plates engraved in a neat and correct manner, and most of the

\* *Traité des ponts, &c. 8vo. Paris 1728.*

the figures are without scales. Under all these disadvantages, it contains every necessary operation for the structure of bridges, with all the imaginable precautions to secure the foundations, and many useful tables and remarks.

SINCE this author's time, we have had our Capital embellished with a very magnificent stone-bridge, which may have afforded much experience in the practical part, to those who had the opportunities to attend upon this building through its different periods, did they do it with requisite judgment. It is to be regretted, that the ingenious and honest \* gentleman, who was appointed over this work, did

\* Mr. Charles Labelie, native of *Vevey* in *Switzerland*, his merit as an *Hydraulick* engineer is further manifested in a very high degree, by a fine plan of a new harbour in the *Downs*, to come up to *Sandwich*, intended some years ago, but the expence then appeared too terrible. A sad principle in the politicks of a nation, either in works of war or peace! when certain and known benefits will attend the contrary, if not to us, to our descendants.

## P R E F A C E.

iii

did not at the finishing of it, publish all the particulars of the mechanism of this grand structure, in a manner he was capable of doing it, to the satisfaction of the curious.

In this little essay I have ventured to give my sentiments upon the choice of arches, and to lay down a new method of my own invention to determine the thickness of a pier, according to the height and base of any given arch, and to the intended length of the pier, from the springing of the arch downwards. In the practical parts, I have consulted the treatise above-mentioned, and another \* author of later date, whose labours have been many years employed with great assiduity for the advancement of every branch of knowledge, necessary to the engineer.

BESIDES these, and other practical writings, much may be picked up from several

\* Science des ingenieurs, par Belidor, &c.



veral modern books relating to antiquity. These may greatly prevent any violence being done to the chastity of ancient models; at the same time that they warm the imagination by their accounts of former grandeur. The works of *Desgodetz*, *Montfaucon*, and *Bergier traité des grands chemins de l'empire*, among many others, are of too great utility to omit making mention of them.

It will not be out of place to observe here, that in all edifices, the just economy of materials, which produces likewise an œconomy in the workmanship, are objects worthy all the attention and skill of the artist, who makes a design, and inspects the execution of it; for how ignominious must it be for an architect (an appellation too often prostituted) not to be able to ascertain the exact dimensions, that will give the due solidity to an edifice? and not by *under-rating* them, to risk its ruin; or by *over-rating* them, occasion such superfluous expences, which  
either



either publick or private, might elsewhere be more usefully employed.

HAVING signified, that the name of Architect is too commonly prostituted, let us give a slight sketch of the qualifications requisite to this character. First, the base of all others, on account of the great trust, should be a perfect integrity; then, as Sir *H. Wotton* observes, "that architecture can want no commendation, where there are noble men or noble minds," it must follow, that the professor of it should possess most of the liberal endowments, and maintain a due connection with other arts and sciences: far from being educated with a trowel in his hand, his education should have been planned, as *Horace* informs us of his own, by the care and indulgence of an affectionate father or parent,

— *puerum est ausus Romam portare,  
docendum*

*Artes,*

*Artes, quas doceat quivis eques, atque  
senator  
Semet prognatos.*

WHAT is observed of the ancient statuaries, in a late very elegant inquiry into the beauties of painting, may be said of their architects; “The statuaries of  
“Greece were not mere mechanicks; men  
“of education and literature, they were  
“more the companions than servants of  
“their employers; their taste was refined  
“by the conversation of courts, and enlarged by the lecture of their poets:  
“accordingly the spirit of their studies  
“breathes through their works.”

\* INDEED, one of our best writers has insinuated, “that it generally is the method of such who are in love with any  
“particular science, to discover all others  
“in it.” — Be that as it may, that great man was certainly mistaken, though perhaps wilfully, to imagine that *Martial*  
threw

\* *Addison's dialogues upon medals.*

threw the cryer and the architect into the same class, in any other parallel than that of the lucrative acquisitions of their professions, and then we shall see, that instead of dull or stupid, for *duri* must be construed griping or tenacious, (in that sense hard) a vice that may influence the morals of the artist, but not his intellects.

*Artes discere vult pecuniosas?*

*Fac, discat, citharædus, aut choraules.*

*Duri si puer ingeni videtur*

*\* Preconem facias vel architectum.*

56 Epig. lib. V.

If what I shall offer should prove useful in the least, my chief ends are answered; my apology to the publick can be no other than the zeal of my intentions, justifiable upon the authority of a spirited writer. I shall give it in his own words and language.

*Ora*

*\* Preconum enim ars tunc temporis ad invidiam fructuosa. Vide 8 Epig. lib. 6. N. Var.*

\* Ora con qual occhio rimirarsi, e con quale cuore da un buon cittadino può soffrirsi di veder gittato il tempo e tanti fini marmi, e tanti danari sì mal impiegati, e quasi dissi perduti in opere che in vece d'accrescere ornamento al nostro † bellissimo paese ne vanno anzi scemando tutto di la bellezza ed il pregio? Ben di ciò si lamenta il nostro M. S. Maffei nella sua eruditissima Verona illustra ed ha da tutto di lamentarsene chiunque ha buon gusto, e sano intendimento; ma non perciò miglioramento alcuno si vede.— Questa considerazione più dogni altra cosa m'ha stimolato allo scrivere e pubblicare questa qualsiasi opretta; che s'ogni liberale uomo è obbligato per la sua patria a porre anco in pericolo, quando per sua difesa abbisognasse la propria vita, molto

\* Proemio del Co. Aless. Pompei agli cinque ordini di M. S. Micheli. Verona 1735.

† This happy island, as richly deserves the epithet. When the Romans had it in their dominion, they thought so.

*Britanniam quod maximum ejus imperii decus est.*  
Spartianus in Severo.



*molto piu deve, e sudori, e fatiche, e quel talento, che o molto o poco, il dator dogni bene a lui concedette, per essa impiegare; ne schivar deve d'incontrare molestie e contrarieta, qual ora per giovare al publico gli convenga opporsi e ad abusi universalmente radicati, e a falsi opinioni comunemente abbracciate.*

THIS excellent critick has sufficiently taken notice of the abuses and corruption in the taste of civil architecture in *Italy*, at first introduced by two rivals and contemporaries, *Bernini* and *Borromini*, just on the spot where the most venerable piles of antiquity offer their glorious remains. These two artists did not introduce their unwarrantable novelties ignorantly, but through a ridiculous affectation of singularity.—And the worst is, that their characters were of consequence enough to give sanction to their follies. — The infection has totally spread through most countries in *Europe*. — It has at last reached this  
2 island

island with the additional mixture of  
 \* *Chinese, Gothick, French, &c.* — Even  
 the designs of *Inigo* have yielded to the  
 caprices of the times. Could one be rea-  
 sonably blamed to wish for a return of  
 the uncultivated rudeness of the barbarous  
 ages? *La rozèzza de de' barbari secoli?*

THEREFORE whatever design may be re-  
 quired of the young architect, let him fetch  
 his rules from the school of † antiquity, let  
 him follow the steps of those great men  
 who first discovered her beauties, tho' de-  
 faced

\* I do not so absolutely condemn these extrava-  
 gancies in the inner decorations and furniture of some  
 particular apartments of a building, or for such works  
 as are made of timber, to be dispersed in different  
 quarters of a garden, park, &c. In such situations  
 they afford an agreeable contrast and pleasing variety.  
 — But then let their beauties be always considered as  
 accidental, and not positive.

† If any object against the dryness of these prin-  
 ciples, — the subject requires it: “ for though in  
 “ practical knowledges, every compleat example may  
 “ bear the credit of a rule, yet peradventure rules  
 “ should precede, that we may by them be made fit  
 “ to judge of examples.” Sir *H. Wotton*.

faced and darkened for ages with the thick mists of a barbarous ignorance ; the most judicious were content to restore them in their original chastity, without the wanton alterations of a misguided fancy ; by their example let him never delineate any thing that has not the truth of science for its basis, that so it may prove past all doubt of irrationality in the execution. *Ita quod non potest in veritate fieri, id non putaverunt in imaginibus factum posse certam rationem habere.*

THIS is a maxim that descended to Vitruvius, who established it by his practice and writings about eighteen hundred years ago.

T H E

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S H O R T



SHORT  
PRINCIPLES  
FOR THE  
ARCHITECTURE  
OF  
STONE-BRIDGES.

SECTION I.

*Of the parts of a stone-bridge.*

I. **A** BRIDGE of stone, or of brick,  
or of any such like materials,  
has two butments which are  
its two extremities, reinforced with proper  
walls.—Sometimes they are raised against  
rocks, or other solid earths, capable to re-  
sist the drift or shoot of the arches, ac-  
cording to the disposition of the place.

B

2.

2. A bridge has one or several openings, called arches, for the passage of the waters of a river, designed of sufficient extent, if possible, that at the times of inundation, the waters may have free course thorough. The number of arches in any bridge, should always be unequal.

3. THE piers serve to support the arches. The faces against the stream, from their foundation up to the high water-line, are generally drawn circular or rectangular. These two fronts are preferable to all others, as they divide with greater facility the current of the water, which afterwards glides thorough the arches intended for its passage.

ALL these things are so differently made in different sorts of bridges, with respect to the materials, the situation of places, to the more or less buttments they require, to the weight of bodies, to the good or bad foundations, that they will require each its particular notices.

BRIDGES have other parts, not so essential as those already mentioned. These are, 1. The parapet with or without balustrade. 2. The banquet, or raised footpassage. 3. The eyes or niches between the arches, and all other decorations judged their proper ornaments, such as turrets, statues, columns, &c.

S E C T. II.

*Of the projects of bridges.*

**W**HENEVER a bridge is projected, the following considerations require due attention.

1. To take an exact plan of the spot where the bridge is intended; this plan must give, very truly and precisely, the extent of the water, the extent of the gravel, if there is any, the borders of the river, and the roads or streets which lead upon the bridge.

2. UPON this plan is designed the project of the intended bridge, with its due number of arches and piers. A bridge must always be placed square upon the stream of the river over which it is built. The angles of the piers \* must never decline from a right-angle, for its strength hereby will be more liable to be diminished.

3. UPON this same plan a line is traced from shore to shore, which is to cut the bridge exactly in the middle of its breadth. This line is marked out in the river by stakes exactly corresponding. The depth of the water is sounded at every fathom, or six feet, or at every two or three fathoms,

\* This is remarkably contradicted at the bridge at *Rimini*, where the sides of the piers form oblique angles, with the two external fronts of the bridge. The only reason I can discover is, that the bridge being fixed to cross the river at that spot, obliged the architect to design the plan of the piers so as to give the water an uninterrupted course through the arches, whose sides are supposed to have been drawn in the same direction with the old stream. *Palladio's* design of this bridge is entirely erroneous.



thoms, as the case may require ; these soundings are to be made with such care as not to deviate from the right line ; they are either done by small ropes, or long poles, with weights at the ends to sink them.

4. THE soundings of the water being finished, and marked upon the plan, by their depths, is drawn a section or profile of the bed of the river upon the spot where these were taken ; this will give the heights of the two shores, the depths of the water, and the bottom under water, whether gravel, rock or sand, to which attention must be had, to mark out their differences in the profile. By two lines drawn across this section, the heights of high and low water must be marked out, they are exactly level, and drawn parallel to each other.

5. THE next operation is by means of an iron sound, of due length to sound the bed of the river. The end of the sound

B 3 is

is barbed like the head of an arrow, only it has four instead of two. It is worked in for some feet into the bottom, and brings upon its barbs such bits of earth as it has met with ; accordingly there must be set down in a memorial drawn up for the project of the bridge, the qualities of the earth it has met with severally specified. Some sounds are made with ends like the end of a gimblet, which turned wrong-ways takes up nothing, and having penetrated the desired depths is turned in its true manner, and brings up with it a sample of the earth it meets with. Where the bottom is very gravelly, a pile shod with iron must be first drove in, and being taken out again, it gives admittance to the sound.

THESE trials cannot be done without great circumspection, and some expence, they are absolutely necessary towards the project of a bridge ; which requires every precaution for the establishing the work  
on

on the most secure principles, and adjusting a true estimate of the cost.

6. HAVING certain informations of the consistence of the different bottoms, whether sand, clay, gravel, rock, &c. the project of the bridge may then go on. The fair plan of the piers and arches is accordingly designed, with all their determined circumstances.

7. THIS done, (in some cases) account must be taken either from authentick records, or from some of the oldest inhabitants in the neighbourhood, of the highest inundations that have happened.

8. ENQUIRY is then made of the materials intended to be employed in the work. For a stone-bridge, the architect must enquire, whence the free-stone is to come, whether soft or hard to cut, how it is to be conveyed, its nature more or less strong, to bear the pressure at the reins of the arches, and their weight: for some

stone is so soft on just coming out of the quarry, that it easily breaks and shatters if the vouffoirs are made too little. What rubble or ragged stones are to be used in the inside work, or perhaps bricks.—The qualities of the mortar that can be made; — afterwards the number of workmen necessary to finish so much work in such a time—for there are only eight months in the year in our climate, that these works should go on vigorously thro' all their parts, from the beginning of *March* to the end of *October*.

### S E C T. III.

*Of the breadth, depth, and rapidity of a river, and to determine accordingly the size and number of arches and piers.*

**T**HE waters of a river run with more or less rapidity, as they are more or less contracted. When a bridge is built upon a river, the piers of it occupy a space equal to the body of water that they have dis-



displaced; and this being forced from its place runs with greater rapidity through their intervals, the arches, and the river gains in depth what it so loses in breadth. If the breadth of a river is diminished one third by the interposition of the piers, and that the depth of this river is only two fathoms, or twelve feet, in the same place, before its course was impeded, it will afterwards increase to be three fathoms deep. This experience is fully proved in any river, for its waters will be found twice as deep in that part, where its breadth is only half of another. The bottoms are here supposed level, and of the same nature and consistence. The increase of the rapidity of the current is also equal to the diminution of the breadth of a river; thus a stream which runs with 10 degrees of rapidity, if reduced in breadth one-fifth, will run with 12 degrees of rapidity in that immediate spot. This increase of rapidity may give an additional power to the body of water to tear up its bed, though before it could not. This  
may

may also take effect at the foundations of the piers, and thereby occasion the destruction of the bridge.

THE more or less declivity of the bed of a river, increases more or less the volume and rapidity of the water below. This declivity, when very sudden, forms what is called a cascade, or water-fall.— The waters above, towards the source, are very still and quiet, while those lower down are very rapid and violent; it was this accident in nature which first taught the use of flood-gates and locks. — Near such places, where a bridge should be required, great precautions must be taken for the security of its foundation by starlings, or the like means, as we shall indicate in a following section.

BRIDGES, if possible, are not to be built in a very narrow part of a river, where there is any probability of the water rising to a considerable height; nor should ever the water be so forced through the arches of

a bridge, as to threaten destruction to the piers; the most effectual means to prevent it, would be to cut away the banks of the river, equal to the space the buttments and piers might occupy in the river. The stream thus relieved for any obstruction, would run under the arches, without any acquired degree of rapidity.

THE breadth of a river may require from one to nineteen \* arches, and more, the apertures of the arches may be from thirty feet to one hundred feet, and upwards. The deeper the river, the narrower arches must be adopted, but so as to be capable of giving free course to the navigation used upon that river.

BRIDGES from three to five arches, may have their center ones much wider than their others. But all above should have their lateral arches to decrease very gradually

\* The *Pont St. Esprit* over the *Rhône* has nineteen considerable arches, besides several small ones, in one of the buttments.

dually in their breadths from the center one. Such proportions will afford the most exact and pleasing symmetry, and augment their reciprocal strength.

THE heights of the banks of a river determine whether the arches should be semicircular, or under ; but this makes no alteration in dividing the breadth of the river into such a number of arches, or in fixing the extents of their bases.

#### S E C T. IV.

##### *Of the buttments of stone-bridges.*

THE foundations of the buttments of a stone-bridge, must have their returns equal to that of the piers, if the disposition of the place requires it.

THE wings, whether carried out at the sides, or in front, must follow the decoration of the work, for the plinths, cordons,



dons, entablature, &c. nor must they interrupt the slope of the bridge.

IN the following problem for determining the thickness to be given to the butments, it is supposed for a bridge of one single arch; because, should the bridge contain many others, it is never but the efforts of the two extreme arches which is considered—for all the intervening arches mutually maintain in their drift, one against the other, an equilibrium; unless these arches are much wider towards the center, than those at the extremities of the bridge. For then it might happen, that the efforts of the greater arches would influence too much the drift of the lesser. The butment, therefore, must be duly strengthened, according to these considerations:

*“ To find the thickness to be given to the  
“ butments of an arch.” (Fig. I.)*

Mr. *Gautier* gives this construction. Prolong the diameter MA indefinitely to C,  
raise

raise the perpendicular AD indefinitely at A.

DRAW AE to the middle of the arch, and with the aperture AE, from the fixed point A describe the quadrant DEB, this will cut AM in B, and AD in D. Now AB, AE and AD are equal from construction, being radius of the same circle; make AC equal to AB.

THEN draw BD to cut the hypotenuse in I; from I let fall the perpendicular IL upon AD, this will be the half of AB. From the point E draw EG indefinitely, to cut AD in H, and carry IL from H to G for the thickness of the butment, which is described by the figure GVHA.

THE demonstration he gives, is as follows. It will appear upon examining this figure, that CB being on a level, and AB being considered as a beam, it cannot remain in that situation, if there is not opposed

posed to it from A to C an equal power on the other side of A, taken as its fulcrum; but AC is equal to AB in power, weight, or length, &c. then AC keeps AB in equilibrium. Now let us suppose AB of a power equal to 90 degrees.

IMAGINE AB raised perpendicularly upon itself at A, as AD, so that inclining neither to one side or the other, it neither shoots towards B or C, therefore it requires no power to sustain it. But as it lay horizontally at first from A to B, we supposed its power to be expressed by 90 degrees.

BUT let it be raised to AE, between AD of no degrees, and AB of 90 degrees, it will in this case have its power expressed by the mean proportion of the power AD of no degrees, and of AB 90 degrees, which is 45 degrees; so that the power of AE is 45 degrees, and therefore the half of AB, which is AN, is sufficient to counterpoise the beam AB at this elevation

tion of AE. Now AN, IL, or HG, are equal by construction, so that AB being to AD, as IL to LD, the shoot AE of the arch AEM will be HG, as that of the beam AB, in an horizontal position, was AC.

THE butments of the lower arches are determined by a similar construction.

## S E C T. V.

### *Of the choice of arches.*

THERE are only two sorts of arches that should be described for bridges, viz. the semicircular, and the scheme arch.

ELLIPTICAL and *Gothick* arches were never admitted by the *Roman* and *Grecian* masters. My own particular reasons to condemn them, and for voting for their entire abolition, are as follow :



1. THE elliptical arch is of a poor meagre and false figuration; it is too much evacuated at the reins. The curve that forms it, and consequently the voussairs, having by construction \* several centers, it cannot be near so strong as an arch whose radii are traced from one center, and therefore it is much less capable to bear the action of some great weight, or of a violent shock, or even its own drift.

2. † GOTHICK arches are of so barbarous an aspect, that it is sufficient to condemn

\* E quanto dir si potrebbe degli arche, & di certe nuove curvature, e di certi nuovi loro ornamenti! Essi piu intorno ad un sol centro n'on s'aggirano, ma o hanno piu centri, o framischiati sono, di linee rette, e d'angoli, tanto che privi restano di quel nervo a reggere cio, che, sovra di se sostentano, necessario, e che alla loro circolare figura naturalmente si conviene. Proem. dal Co. Aless. Pompei agli cinque ordini di M. S. Micheli. *Verona* 1735.

† I had fixed my objections before the following note presented itself to my notice.—As for those arches which our artificers call of the third and fourth point, and the *Tuscan* writers *di terzo* and *di quarto acuto*, because  
C they

denn them upon this account alone.—  
 The inspection of their summits shews,  
 that this arch is made up of the mangled  
 portions of two curves intersecting one  
 another with a harshness as grating as the  
 most repugnant lines in nature.—The su-  
 periority of their strength, alledged by  
 some, is not a sufficient motive, all things  
 considered, to render them acceptable.

3. THE *Catenarian* arch has all the dis-  
 agreeable appearance of the *Gothick*, and  
 therefore as little eligible; for the archi-  
 tecture of the whole, and every part re-  
 quires a strict congruity in all its lines.—  
 Indeed it has the peculiar property from  
 its construction, that all its vouffoires being  
 of equal weights support themselves in  
 equi-

they always concur in an acute angle, and do spring  
 from a division of the diameter into three, four, or  
 more parts at pleasure; I say, such as these, both for  
 the natural imbecillity of the sharp angle itself, and  
 likewise for their very uncomeliness, ought to be exiled  
 from judicious eyes, and left to their first inventors  
 the *Goths* or *Lombards*, amongst other reliques of the  
 barbarous age. Sir H. Wotton.

equilibrium; but as this property can be given to the vouffoires of the semicircular arch, as we shall hereafter notice in its proper section, let us request to have this arch for the future confined to the regions of speculation, with many other valuable discoveries in theory, which require more than human ability to bring them into real practice and execution.

## S E C T. VI.

*To describe an arch of any given height and base.*

**T**HE arch we mean to describe (Fig. 2.) is called a scheme arch; it has its base AB equal to that of a semicircle, and its height is taken upon the perpendicular radius CD; the most common heights are either CE two thirds, or CF the half of the radius. But the height of the arch may be fixed occasionally at any other

intervening point at pleasure. \* This was the practice of the ancients, where the semicircle was found too high.

For the construction. First draw AB for the base, bisect it at C by an indefinite line at right angles. Suppose CE for the required height of the arch; from the points E and A describe the intersections at X and Y, and through these draw a right line to intersect the indefinite perpendicular O; then with OA taken for radius, describe the arch AEB, whose given height was CE, and whose base is AB.

In the same manner any other may be described, as AFB, &c. &c. &c.

In arches where a greater height would be required than the radius CD, (Fig. 2.) the base of the arch may be taken at  $r, s,$   
to

\* Et plutôt que de les surbaissier par des ellipses ils ont mieux aimé se servir d'une portion d'un plus grand arc, comme j'ai remarqué au pont du gard.—  
*Traité des ponts.*



to which the lines of prolongation *Ar* and *Bs*, are drawn perpendicular ; but *Ar* and *Bs* must never exceed a sixth part of the diameter of the arch.

“ OF all others (says Sir *H. Wotton* of  
“ arches) those are the gracefulest, which  
“ keeping precisely the same height as a  
“ semicircle, shall yet be distended one  
“ fourteenth part longer than the said di-  
“ ameter ; which addition of distent will  
“ confer much to their beauty, and de-  
“ tract but little from their strength.”

## S E C T. VII.

*Of the archivolt, key-stone, and voussairs.*

THE desired arches being traced according to the determined bases and heights, the archivolt, when one is intended, is next to be described by a parallel exterior circle from the same center, the interval between the two circles

C 3 should

should never be less than a fifteenth of the aperture of the arch. This proportion has been observed at that venerable pile of antiquity the Pont du Gard. — In others it has the tenth, and sometimes the twelfth of the opening of the arch \*. But these measures are not applicable to arches under thirty feet for their bases : for these let the following regulation determine.

AN arch of six feet aperture requires the key-stone and archivolt of one foot and a half, and an arch of thirty feet diameter requires only two feet ; therefore to all the intervening arches, from six feet to thirty feet, allow to every foot of extent in the diameter half an inch to the archivolt. Thus an arch of twelve feet in the base will have an archivolt of one foot nine inches ; and so for the rest.

THE

\* The lengths of the key-stones always exceed by a little the breadths of the archivolt ; and in fixing the lengths of the voussiors, regard must be had to the softer or harder qualities of the stone.

THE vouffoirs are all the stones which compose the archivolt; their joints being prolonged tend to the center of the arch, and are part of the radii drawn to intersect its circumference, the two vouffoirs at each extremity rest upon the impost. In the next section, the manner in which an arch is said to shoot, shall be fully explained.

S E C T. VIII.

*To find how the shoot or drift of an arch is made. (Fig. 3.)*

IF one considers the arch YAZ having a number of equal vouffoirs, these vouffoirs are cut in such a manner, that their joints prolonged unite in the center of the semicircle: so that the vouffoirs being wider at their convex parts than at their concave, must be looked upon as wedges which support one another, and mutually resist the efforts of their weights which dispose them to fall.

Now let OADF mark the centers of gravity of these several vouffoirs, and beginning at the key-stone draw through the points A and O a line AV, perpendicular upon the face C, and through the points A and D draw another perpendicular AP. Upon the side B draw likewise another, DQ upon the face E; and suppose perpendiculars drawn upon the face of every vouffoir. This stated, consider the key-stone as supported by the two adjoining vouffoirs, as by two inclined planes, it acts in the same manner as a wedge, which being introduced into a body, tends to separate it in two by an effort which is made according to the directions AB and AC, perpendiculars to the two inclined planes BI and CI. For one may here take the weight of the wedge for the power which acts upon it. Thus the two powers which sustain the sides BI and CI in equilibrium, against the force of the wedge, will act according to the directions of AP and AV, which are perpendiculars



pendiculars to the faces of the same; and as these directions unite at the center of gravity A, where it is supposed that the whole weight or power of the wedge is collected, it may then be asserted that these sustaining powers require so much the more force as the angles PAI and VAI will be more open, or which is all one, as the faces BI and CI are less inclined from the vertical AI; for if the sides of the key-stone were infinitely little inclined, or were almost perpendicular to the horizon, the directions of the powers P and V being in this case, in one right line directly opposite to each, it would require an extreme degree of force to support the weight of A, taken for that of the key-stone; whereas the more the angles are acute, formed by PA and VA upon the line AI, the less power will be requisite, since their directions not being then so opposite one to the other in a right line, they will act the more forcibly to support the weight at A.

WHAT has been shewn for the key-stone, may also be considered for the voussoirs D and O.—Let us take the voussoir D for example, which having by construction the figure of a wedge, will likewise endeavour to drive off the adjoining faces, but not so forcibly at E as A acts upon B, because the plane EI being more inclined than the plane BI from the vertical AI, the angle QDK, formed by the QD and DK, is more acute than PAI. In the same manner the voussoir F will make still less effort against the face G, than the foregoing one D against the face E, because the angle RFL is more acute than the angle QDK. Now as all the sustaining powers from the key-stone, to that which is laid horizontally upon the pier, will always take effect according to such directions as will make the angles more acute upon the perpendiculars, let fall from the centers of gravity of the voussoirs, their efforts will go on in diminishing; and as these powers have been

I

sup-

supposed equivalent to the efforts of the voussairs, it then follows, that the voussairs act with less power according to their several declinations from the key-stone to the pier.

It must however be observed, that the voussair which is above another, has more power to push the under one, than this has to drive it off; and as the voussairs from the key-stone, to the springing of the arch, act gradually with a less degree of force upon those which are immediately under them, the uppermost always diminishes its power, as the planes EI and GI are more inclined to the horizon; because then these planes support a greater weight, consequently that which tends to fall takes less effect against the resisting power, so that the efforts of all the voussairs in descending from the key-stone to the impost, diminish in the same proportion as they increase in ascending from the impost to the key-stone.

As

As there must be upon the base of the pier a point whereon terminate all the efforts of the half arch, it must be remarked that this point coincides with the angle S, and must be looked upon as the fulcrum or prop of a lever, which indeed is not sensible to the eye, but is not less so in reality, as will appear by what follows.

If the shoot or drift of an arch was not divided along each quarter of the circle AY and AZ, but was all fixed to the two points, as Y and Z, this would produce on both sides such a bended lever as YSH, whose powers would be applied at the extremity Y of the arm SY, and the weight which is equivalent to the strength or resistance of the pier at the extremity H of the arm SH. But as there are as many powers as there are vouffoires, excepting the two Y and Z, which have no shoot because of their horizontal situation upon the impost, therefore every power must have its own particular lever, and its lever  
may



may be expressed by a line placed in its stead. Now as these lines can be no other than the perpendiculars SP, SQ, SR drawn so upon the lines of direction of the sustaining powers PD, QF, RG from the fulcrum S, it is easily perceived to what all this mechanism is reduced ; so that to proportion the thickness of a pier to the shoot of an arch, the effort of each voussoir must be known with respect to its own absolute weight, and the perpendiculars SP, SQ, SR, &c.

THREE consequences may be drawn from what is already said on this subject.

I. THAT in an arch whose voussoirs are not connected by any cement, as we suppose in the case here offered, the narrower they are at their heads or convex parts, the greater drift the arch will have, for the more their faces approach to the vertical AI, the longer will be the perpendiculars SP, SQ, and SR, which are  
taken

taken as the several arms of the levers, and this will accordingly increase the drift of the arch.

2. THAT the thicker the arch is at the summit, the greater will be the drift of the arch; for this increases the weight of the vouffoires nearest to the vertical AI, and consequently they will make a greater effort to fall.

3. THAT the higher the piers are from their bases to their imposts, they must be made wider, the better to resist the shoot of the arches, which is increased by the levers SP, SQ, SR being made longer from every additional height of the pier.

LET us now come to mention how the vouffoires of the semicircular or scheme arch may be described, to increase in a due proportion the weight of each vouffoir, as it declines from the perpendicular that passes through the center of the key,

key, and by these means that they all may support one another in equilibrium. This will be adopting the properties of the *Catenarian*, without admitting the disagreeable figure of that curve.

(Fig. 4.) FROM the center A set off AB equal to  $fa$ , the breadth of the archivolt at the key-stone, let the point B serve for the center of an eccentric circle to describe the heads, or convex sides of the vouffoirs, with the interval  $fB$ . Thus each vouffoir declining from  $fa$  towards  $Cd$ , and lower, acquiring a due additional weight, will also gain the desired property, &c.

THIS artifice should only be executed for the inner work, and not to appear on the exterior revetment, or faceings of the arch. It was very skilfully adopted and practised at *Westminster-bridge*, as may be seen from a longitudinal section, by which the soffets or vaults of the arches  
are

are rendered firm and solid in the greatest possible degree.

M. *Gautier* advises to have all the vouffoires so exactly jointed, that they might lay one \* to the other as smooth as possible, without any cement, and only to point the outside of the joints with some very fine mortar. When they are laid upon mortar, however good it may be, their prise one to the other is not by a thousandth part so strong as the smooth faces of the vouffoires, and other large stones † one upon

\* In the ingenious account of the bridge at *Rimini*, by *T. Temanza* a *Venetian* architect, he says, that all the vouffoires, and other stones of that fine work, have their faces that lay one to the other so exactly jointed, that a hair could not pass between them. He believes that there were particular artificers among the antients, whose business was thus to smooth the joints of the stones, and quotes the *Theodosian* code as making mention of such, by the title of *Quadratarii*.

† Where the faces of stone are thus curiously smoothed, it precludes almost entirely the air, this strengthens their adhesion, and contributes to the duration of all the interior parts.



upon the other ; for mortar, or other cement, only secures a work in the union of small materials, where it becomes a considerable part of the whole mass ; but great blocks of stones are superior to the weak alliance of any cement, their reciprocal adhesion one to the other insures the solidity of the pile, not forgetting how greatly their mere weights contribute thereto. These considerations are not intended to exclude the necessary precautions of iron pins, which the ancients used to fix in the lower stones, well foldered with lead, and also covered them with an integument of the same matter, to prevent the bad \* effects of the rust from the penetration of moisture, which will always make its way however intimately the faces were in contact, or the joints closed. — These pins were admitted of the lengths they

\* These effects are noted by *Leon Batista Alberti*  
Sed nos ex veterum operibus intelleximus ferrum corrumpi & nequicquam durare : æs vero durare & propè æternum esse, quin & ferri rubigine marmora commacerari & circumrumpi adverti.

they stood out from the under stones, into the upper ones.—It was only the external stones of an edifice that were secured with these pins : each vouffoir of the bridge of *Rimini* has three.

### S E C T. IX.

*To determine the thickness of the pier of any given arch, the length of the pier from A, the springing of the arch, to the foundation p not exceeding AC, the half of the diameter AB. (Fig. 5.)*

**P**ROLONG the diameter AD indefinitely towards Y and Z, draw the chord of the quadrant AD.

DIVIDE AD into two equal parts at G, from the point G let fall the perpendicular GK, upon the base AB set off the interval Ak from A to *n*, for the thickness of the pier of the arch ADB. Then draw the tangent at A at right angles with AB, and thro' *n* a parallel line to the tangent,  
set

set off  $Dx$  for the thickness at the key-stone \*, and draw  $sx$  an indefinite line parallel to  $AB$ , afterwards  $yp$  for the foundation of the pier, and the construction will be finished.

To determine the thickness of the piers of any of the lower arches, draw their chords from the point  $A$  to the perpendicular  $D$ ; then with the interval  $AG$  describe a portion of circle  $GHIO$ , and from the points of its intersections, with the chords, let fall the perpendiculars  $Hl$ ,  $Im$ , to intersect the base  $AB$ ; and the intervals  $Al$ ,  $Am$  will give thickness required, for the piers of the arches, which have their heights raised, as  $CE$  and  $CF$ , upon the common base  $AB$ .

BUT the thickness  $An$  is to resist the effort of two half arches, as  $AC$  and  $Wn$ ; therefore it must only be  $At$  that is to be considered as the thickness to bear the effort of the half arch  $AD$ .

D 2

Now

\* According to the rules laid down in Sect. VII,

Now though it is usual to consider no sensible thickness in the superficies of figures, yet we may suppose their superficial dimensions to stand for weights; and when all the parts of a figure are homogeneous, its powers are expressed by the value assigned to the lines which circumscribe its superficies.

For a demonstration of the problem we here give, let us consider the half arch as made up only of two parts; the one fixed as  $tAwr$  upon its base  $tA$ , having its center of gravity fixed within  $tA$ ; the other,  $swxD$  acting as a wedge, introduced between  $sw$  and  $xD$ , will endeavour to drive off the part  $tAwr$  in proportion to their reciprocal magnitudes; therefore the superficies of  $tAwr$  must never be found less than that of the part  $swxD$ ; for if that were allowed, the efforts of the wedge would soon make way and fall through the two inclined planes, to the destruction of the arch.

THE



THE resisting powers are supposed as equal on the side  $xD$  of the wedge, as on its side  $sw$ .

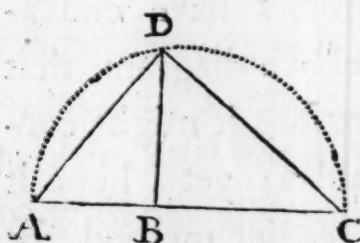
THE tables M. *Gautier* lays down in his treatise he composed from a long experience and observations, I have endeavoured to describe the above diagram, that through its several operations it might correspond nearly to his tables; yet I hope it will be found a much readier method for the intended purposes, and not so liable to occasion mistakes.

IN cases where  $Ap$  is required shorter or \* longer than the semi-diameter  $AC$ , take the mean proportional of half of the required length of the pier, from the point  $A$  to the bottom of the foundation of the respective interval  $Ak$ ,  $Al$ ,  $Am$ , &c. according to the intended arch. For example, let it be  $Aq$  for the desired height of the pier, equal

D 3 to

\* On such occasions, where the piers of an aqueduct were to be determined, it can be solved by this problem.

to 15 feet, the half of it is seven feet and a half, these added to  $Ak$ , taken for 10 feet, make  $17\frac{1}{2}$  feet: the half of this last product is  $8\frac{1}{4}$  feet for the thickness of a pier that has  $Aq$  equal to 15 feet.



\* OR this is found by geometrical construction; make AB equal to the half of  $Aq$ , and BC equal to  $Ak$ , join them together in a right line, and on the whole AC describe a semicircle ADC, and draw BD at right angles to AC from the point B, and let AD, DC be joined. Thus DB will be found the mean proportional between AB, BC.

By the remains of antient bridges we learn, that the thickness of the piers was the third part of the arch's aperture, and sometimes the half of the said aperture. The moderns have imagined this to be more than a sufficient breadth, and have fixed

• Euclid. VI book, 13 prop.

fixed the thickness of a pier to one fourth, one fifth, one sixth, &c. of the arch's extent; the vague and uncertain rules they lay down cannot serve, to any effectual purposes, on that head.

THE antients, who have left behind them full and various proofs, that all their works were undertaken and executed with rationality, and according to the best rules of science, could never have allowed so great a thickness to the piers without sufficient cause. It is well known that in *Italy*, as in other mountainous countries, the rivers are liable to terrible inundations, the rapidity of their streams is increased by the declivity of their beds from their sources downwards. The great inundations of the *Tiber*, tho' not periodical, have happened frequent enough to break down its bridges, without the assistance of the devouring jaws of time; they have oftentimes been buried deep in water, and in such situations the summits of the arches must inevitably have been torn away, if the thickness of

the piers had not afforded them sufficient resistance.

I have with great astonishment seen the marks to which the *Tiber* has rose in the latter ages; they are inscribed against the outward wall of the church of *St. Maria alla Minerva* in *Rome*. — There, at the height of fourteen *Roman* palms above the pavement of the street, is this inscription,

*Redux, recepta, Pontifex*

*Ferraria*

*Non ante tam Superbi*

*Huc usque Tybridis*

*Insanientes, execratur*

*Vortices*

*A. D. M. D. XCVIII.*

UNDER it, at a mark twelve and a half *Roman* palms, is the following,

*A.*



*A. D. MDXXX*

*Octav. Idis. Octob. Pont.*

*vero SS<sup>mi</sup> Dni.*

*Clement. Papæ VII. ann. VIII.*

*Huc Tiber ascendit, Jam*

*Obruta tota fuisset*

*Roma nisi huic celerem*

*Virgo tulisset opem.*

To judge further how the pier of a certain breadth is able to support the two half arches.—Let it be supposed, than an equivalent quantity of materials, to their contents, was placed immediately upon the pier, and considered only as a column, the heights and diameters of the orders of architecture, we are convinced, are established upon just measures of beauty and strength.

Now any pier under the above supposition, whose thickness and height answers nearly to the proportion of a column, may justly be said to have its full proportion  
of

of strength. Two examples will serve to verify the truth of this supposition.

1. IN the semicircular arches A and B, whose opening we shall lay down at 40 feet, the thickness of the key-stone 4 feet, that of the pier 10 feet, the height from the springing of the arch to the foundation 20 feet. Then we shall soon find how many breadths this pier will give in height.

For the superficial dimensions of *yacdbx*

$$\text{(Fig. 6.) } 44 \text{ by } 10 = 440 \text{ feet}$$

$$defg - 20 - 4 = 80$$

$$\text{For the triangle } ep g \ 60$$

$$\text{For the triangle } ep b \ 60$$

$$\begin{array}{r} 200 \\ \text{For the same in the arch B } 200 \end{array} \left. \vphantom{\begin{array}{r} 200 \\ 200 \end{array}} \right\} 400$$

---

840 feet.

THIS answers exactly to a column whose height is about eight times and a half its diameter, and approaches near to the symmetry

metry of the *Dorick*, that perfect model of strength.

2. FOR the second example we will take the two scheme half arches C and D.

THEIR semi-diameters are each 20 feet, the thickness of the key-stone 4 feet, that of the pier 13 feet, the length from *b* the rise of the arch, to the foundation *x*, 20 feet, the measures will be as follow, (Fig. 7.)

For *yacdbx* 34 by 13 = 442  
*defg* 20 by 4 = 80

The triangle *efg* — 60

The triangle *epb* — 20

|                                            |     |   |     |
|--------------------------------------------|-----|---|-----|
|                                            | 160 | } | 320 |
| For the quant. of the $\frac{1}{2}$ arch D | 160 |   |     |
|                                            | 320 |   |     |

Feet 762

THESE dimensions in height amount to about four times and a half the thickness of the pier : and this proportion is indisputably beyond any suspicion of weakness.—

ness. — The first *Dorick* columns did not rise in height much more, as appears by those of an antique temple at *Pesta* near *Salerno* in the kingdom of *Naples*, and others in *Greece*; all are without any bases.

THE thickness of a pier between two arches of different heights and breadths, is determined by taking the thickness allowed to the greatest half arch, and the thickness required for the lesser half arch; and these two quantities, added together, give the thickness for the intervening pier.

## S E C T. X.

*Of the plans, sections, and elevations, of  
decoration.*

THREE plans are generally necessary for the fabrick of a bridge. The first is that of the foundation under the piers, with the particular circumstances



ces attending it, whether gratings, piles, planks, caissons, &c.

THE second is the plan of the piers and arches, with the spandril walls and cross walls, whose interstices are filled with materials less expensive than free-stone, such as chalk, flints, coarse sand or gravel; but they must be well beat in by layers, without the least mixture of earth, for fear of perishing the solid masonry, and especially the vouffoirs.

THE third is the plan of the superstructure, with the paving of the road that goes over the bridge, the banquet of flat stones on each side of it, and raised a foot or more above it for the passage of people on foot. The breadth of the *Pont Neuf* \* at *Paris* is sixty feet; the thirty in

\* This bridge was built upon the designs of *Fra Giocondo Veronese*, a man of universal knowledge; he first restored the text of *Vitruvius*, which he says was neither legible or intelligible; he was invited into  
*France*

in the middle is allowed for carriages on each ; the foot way is fifteen feet ; half of this breadth on both sides, is taken up by stalls of pedlars of different wares.—This should by no means be imitated. — The breadth of a bridge for a great city should allow passage for three carriages and two horsemen abreast, with a banquet on each side for three foot passengers in the same manner.

THE breadth of other bridges, either in the country, or in towns of less concourse, allow them carriage-way for two abreast, and the banquet on each side from three to five feet broad.

THREE sections are necessary to display the materials employed in the interior elevations, and their dispositions ; one longitudinal, taken upon a line drawn exactly in the middle of its breadth throughout its entire length, from one butment to the other.

THE

*France* by *Louis XII.* for this and other buildings ; he travelled to *Rome*, and other parts of *Italy*, and died in his own country in a decrepid old age.

THE second upon its breadth, taken through the summit of an arch.

THE third also upon its breadth, taken upon any one pier.

THE elevation of a bridge is figured in one design, for both fronts are made and decorated alike. It would be an unaccountable innovation to make them different. In this elevation is expressed the exterior aspect of the materials with which it is raised, and in what manner they are worked and decorated.

By the decoration of a bridge is understood the same as of any other edifice, where the skill of the architect is employed in the proportions of the parts to the whole, and adjusting the variety of members and parts of the orders in their suitable places.—The parapet of a bridge stands upon the cordon or plinth that runs across each pier, and over every key-stone. — Oftentimes this plinth is left plain, or at  
most

most only a quarter round, with a narrow fillet underneath; however, it is sometimes changed into a cornice with blocks or modillions, then all the other parts are adorned suitably. The key-stone and archivolt must have their mouldings. The voussours will also admit of ornament. The piers may have niches, with or without columns, entablatures, pediments, consoles, festoons, &c. The parapet has its particular cornice and plinths, with or without a balustrade of stone, or of cast metal like that at the *Ponté St. Angelo* at *Rome*. It has also, at certain distances, pedestals, which may be crowned with globes, vases, pines, or statues, heroical or emblematical, or first a column with its entablature, and then the statue, vase, &c.

**TRIUMPHAL** arches, colonnades and porticos, are sometimes imagined for a superstructure, in imitation of *Trajan's* arch upon the mole at *Ancona*, or the *Ponté Rialto* at *Venice*, or that still more magnificent



ficent design in *Palladio* for the same place — But I cannot recommend the examples as worthy imitation, such immense superstructures are better disposed in large squares and streets of grand avenues, especially in climates where the weather would for the greatest part of the year forbid the enjoyment of them: add to this, that a bridge should not only have all the appearance of being light and airy, but be so in reality.

## S E C T. XI.

### *Of the foundations.*

**T**HE foundation of a butment, (Fig. 8.) when raised against a sloping bank of good sound earth, gravel or rock, is carried on by returns at different heights, as A, B, C. It is easily conceived, that the intention of this hint is to save materials and labour.

**T**HE foundation of the piers is always to be made with projections, (Fig. 9.) as

E

C,

C, D, E; when the bottom of a river is of good consistence, the projection at bottom is one fourth of the height LM from L to H; but when the bottom is suspicious, the third, or one half of LM is allowed to project from L to I.

To gain these projections without an additional expence of materials, let them be taken from the thickness given to the pier in its full length. For example, if the intended thickness of a pier was found to be seven feet, give it only six feet all the way down to the base, and let the thickness at the base be eight feet, and it will make a projection of two feet. Let it be remember'd that we have in Sect. VIII. Fig. 3. said that the angle at the bottom of the pier is the point of rest, or fulcrum, where the drift of the arches coincide.

\* *M. Belidor* relates to have seen a powder magazine, whose vault split asunder on each side in the middle of its reins, and the

\* *Science des ingenieurs*, Liv. II. p. 29.

the whole length of the building, very little time after it had been finished, altho' the dimensions of the piers and counterforts exceeded greatly what was necessary to sustain the shoot of the vault, and the work well finished; upon his examination how this accident could have happened, he perceived that the ground had given way at the extremity of the counterforts. This would not have happened, if they had taken the precaution to have laid two or three stout planks at the foundations, to have had the point of rest entirely secured.

*Scamozzi* gives four methods to lay the foundations of bridges, which may here with propriety be mentioned. He \* declares,

E 2

\* The architecture of a bridge should be determined according to the spot where it is to be situated. In the midst of a flourishing metropolis, it would be absurd not to have it suitably decorated; for, according to *Cicero*, in any works of architecture, this should be decided by judgment and taste, *cujus finis est usus, ad quem accommodanda est ædificandi descriptio: & tamen adhibenda est commoditatis, dignitatisque diligentia.*



clares, that the decoration of bridges should be in a rustick and plain style of architecture.

I. THE space for the foundation of each pier is enclosed with a dam or water-stop, raised with two rows of piles, whose heads must be higher than the level of the water; the space between them is filled with clay, or chalk well closed in, so as to form a bank, which can stop out the water from the spot where the pier is to be founded; the water is taken off by buckets, or some other convenient engine, from all the inside of the dam, that the workmen may work dry upon the bed of the river; and according to the nature of its consistence, the foundation is laid upon piles, planks, &c. but this method can only take place where the river is neither rapid nor deep.

THE second expedient is to lay the foundations, well united together with pins or cramps of iron soldered in, and covered with lead,



lead, upon rafts or gratings of good hearty oak-timber, very strong and well fastened together; these are buoyed up upon the surface of the water by strong cables fixed to other floats or machines; then they are let down with the work that has been raised upon them, very easily and level to the bottom of the water. — This method requires a good bottom, very smooth and level. — It was practised by the emperor *Claudius* in the port of *Ostia*, and by *Draquet Reis* in the last century at *Constantinople*, for the foundations of the fine mosque he ordered to be built in the sea.

THE third is to turn off the water of the river into another bed, or into some very deep dykes; but then the foundations must be worked up as expeditiously as possible, that they may have taken good hold, and be well settled, before one may be obliged to turn the river again into its old channel.

THE fourth and last, which he believes was the method used for the construction of *Trajan's* bridge across the *Danube*, is to cut a new channel just near the place where the river makes a great elbow, and then stopping out the water from the spot where the bridge is intended to be built, turn it through that channel cut for its passage.

THIS method which he approves as the best and safest, will allow time for the work to go on leisurely, and always on a dry bottom. The work finished, the water is admitted into its old bed, and the channel filled up, and its two entrances into the river well secured.

To lay the foundation of the piers of a bridge, if the bottom of a river is clogged with loose earth and mudd, piles must be drove in round the intended spaces, after as much of it is taken away as well can be; the same must be done if there is any  
loose

lose sand or gravel, then clay or chalk must be thrown in, which must be well rammed and beaten.

*Blondel* has affirmed, that whatever precautions an architect may take for the security of foundations of any fabrick, yet herein he works with great uncertainty, and merely by conjecture. For who assures him, that building upon a bottom of seeming good consistence, (after all the necessary researches) there is not an unforeseen defect that may occasion the downfall of the edifice?

AN accident of this nature happened, says *M. Gautier*, at one of the isles of *Oleron* or *Ré*, where a part of the walls of a fortification were overthrown, tho' built upon a rock. This was owing to a cavity therein, which could not be foreseen.

BUT *Blondel* relates, to confirm his assertion, that the thick walls of the church

of *Val de Grace* at *Paris* gave way on one side, though built upon a good bottom, because at some fathoms lower than their foundations, there was afterwards discovered great cavities, which had been formerly quarries of stones.

*M. Angelo Buonarota* built the cupola of *St. Peter's* at *Rome* from the very foundations with all imaginable precautions; however, since that time it has received a considerable fissure. This has been remedied by a cincture of iron, of great thickness, surrounding its entire periphery. It was by some thought, that this fracture in the dome was occasioned by the waters descending from the *Vatican*, and *M. Janiculo*, that had undermined and sapped the ground under some part of the foundations of this vast pile: indeed this, or some other subterranean accident, might have been the occasion of the crack in the cupola. Though, according to what  
is



is mentioned by \* *Bonanni*, after all examinations made by order of *Innocent XI.* it was solemnly declared to have proceeded from some defect in the bad construction in carrying up the building. To which may be added the passages, galleries and stair-cases behind the statues of *S. Veronica* and *S. Andrew* in two of the main piers; these passages, galleries, &c. were made before *Bernini's* time, who only designed the decorations to them. — But yet the popular clamour had almost made him fall a victim in this affair, as the crack was then a fresh and constant matter of talk.

A story is told, that *Bernini* meaning to be jocular with *F. Mochi*, who had made the fine statue of *S. Veronica*, all whose elegant and airy drapery appears to be blown aside with wind, asked him, whence comes the wind that fills the drapery of the saint as she stands in the niche?

*Mochi*

\* *Templi Vaticani historia.*

*Mochi* piqued at the raillery, answered, from the crack you have made in the cupola. This is said to have happened in the hearing of the pope; upon which *Bernini* precipitately left *Rome*, and did not return till the affair was cleared up, and he entirely acknowledged innocent.

THE construction of domes, and the arches of bridges, being established upon the same principles, the above digressions may not seem out of place.

FROM these, and several other similar casualties, *M. Gautier* concludes it next to an impossibility to answer for the foundations of an edifice.

THESE following are the directions he gives to secure the foundations of buttments and piers. They may serve for quays, moles, light-houses, batteries, &c.

1. By a jettée of large pieces of stone or rock, carried upon the intended spot, and laid level to a certain height.

2. SEVERAL large gratings of timber laid level upon these large stones, at a certain depth under the surface of the water.

3. By caissons laid upon these gratings, filled with materials regularly built up to the surface of the lowest ebb, having good quoins and facings of free-stone outwards, to bear the beating of the waves when the caissons are perished.

4. THE same work still carried on upwards to an assigned height above the highest tides; and here the quoins and facing must be worked in the strongest manner, to withstand the constant violence of the most tempestuous waves.

(Fig. 10.) IN laying the foundations of a pier upon planks, as A, the bottom must  
be

be first well examined, and if not found of proper consistence, it is help'd by a thick stratum of chalk, as B; then the piles are drove in, and over them is placed the frame, across which the beams are fixed, and the planks are nailed down with stout wooden pins.

(Fig. 11.) AT other times a grating is framed together, and let down upon the bed of the river. The piles then are drove in the compartments of the grating diagonally, beginning by those of the middle, and so proceeding outwards; for if they begin by the exterior piles, the ground would be so jammed as not to admit the inwards piles to be drove in. Besides the piles drove in the space whereon the foundation is to be raised, other piles are drove in all round the grating; this is called border piling. — They are either round, as RR, or flat ones grooved into one another, as QQ.



BUT there is another method of grooved piles, (Fig. 12.) wherein three-plank piles are inserted between two round piles, whose heads are steadied by two parallel slips *a, a*, that run the whole length of this piling. These slips are fastened with pins, to prevent any of the piles from getting out of their grooves.

BESIDES driving piles in contact one to the other for border piling, they may be drove only on the sides of the caissons, as was practised at *Westminster-bridge*, in single, double, or triple rows, at such intervals as the security of the foundation may seem to demand their being drove, at a greater or lesser distance one from the other.

PILES are either shaped square or round, they are made of any wood that will not rot under water. Oak and firr are chiefly used. The pointed ends of piles are armed with iron spikes. The spike has a cap

to let in the end of the pile, and four straps with holes to nail it on. The point of the iron spike, instead of being an acute angle, (Fig. 13.) should be made rectangular; this would save a superfluous expence of iron, and render it more able to break and penetrate into any hard obstacle it might meet with under ground, before it could be driven to the intended depth.

WHEN the foundation does not require very long piles, and that the consistence of the ground gives them easy admission, it will suffice just to burn their points to harden them, without having them shod with iron. Every pile, however, must be shod round its top with a flat iron ring: the use of it is to prevent the violent strokes of the ram from splitting the pile.

ON driving piles, the strongest and longest are to be used on the outward borders; for in process of time, if any unforeseen

seen accident should fall out, it will with greater probability happen to the outside than in the middle. To work with precaution, many little attentions must be had to the manner of piling, to take all advantages from any new circumstance that arises.

THE length and thickness of piles are regulated according to the nature of the ground into which they are to be driven. The trial is thus made : drive in a pile or two here and there till the ram takes no more effect upon it, hereby you will discover at what depth the bottom makes a sufficient resistance, to judge of its solidity ; then observing how many feet the piles have entered, you may judge from thence nearly of the length your piles for the work must be ; I say nearly, because they must be allowed still a greater length, for in many places the ground may admit them in deeper than it did in the experiments.

HAVING discovered the length the piles are to be fixed at, in the next place you must determine their thickness.

THE diameter of a pile should be the twelfth part of its length; for example, those of twelve feet long should be one foot in diameter: but this rule only holds good in the smaller sort of piles, from six feet to twelve feet long; for when they are eighteen or twenty feet in length, their diameters must not exceed sixteen inches.

THE thickness of plank-piles is also fixed by their lengths: if six feet long, their thickness should be from three to four inches; and if twelve feet, it may be from four to five inches. Plank-piles need never exceed this length, the breadth of a plank-pile is from one foot to fifteen inches. These are armed also with spikes, if the hardness of the ground requires it, and their tops are bound with iron to prevent their splitting by the strokes of the ram.

WHEN



WHEN a pile or plank-pile is to be driven obliquely into the ground, their points are only sharpened on one side, and then they will enter according to their intended inclination.

ALL the grooves in any piles must be made full wide enough, to admit the insertion of the others with entire ease and liberty.

THE piers of a bridge are oftentimes obliged to be secured by starlings, whenever they have not had their foundations at first carefully laid, or that the water has found means to undermine them by any alteration in the current, and so tears up the bed of the river; this evidently menaces the destruction of the bridge; and though starlings, by occupying a greater space in the river increase its rapidity, yet in such a case, the lesser evil must be accepted, in order to avoid a greater.

THE starling of a pier is a jettée, made at a due distance from the pier, and surrounds it; this space is bordered round with piles and planks, and then filled up like a dam with great pieces of rough stone, or others; these thrown in, sink into those cavities the water has worked at the foundations, or under.

WHEN the jettée is compleated, the surface of the starling shews by its depression when there are more vacuities below, and that it requires a supply of materials laid upon it to answer the removals at the bottom, for the security of the pier. This requires a constant inspection. M. Gautier had recourse to this method at the bridge of *Toulouse*, where the base of one of the piers was in this ruinous condition. There yet remains something more to be said concerning foundations, before we close this section.

THE

THE canal of *Languedoc*, which joins the *Mediterranean* to the *Ocean*, is a work worthy of any nation in its highest pitch of grandeur. Mountains were cut through, channels were built across a river for its passage. The bridge of *Cesse* was raised for that purpose, whose arches bear upon them a body of water equal in length to the breadth of the river it crosses, and broad and deep enough for the navigation of the boats and barges, with ways on each side for the men and horses that draw them.—Yet the foundations of this pont-aqueduct are built only upon shoals of large pebbles, which form together a sort of solid petrified bank.—But in a hundred places where these shoals might be, not one perhaps might prove favourable to fix foundations upon.

WE have heretofore mentioned caissons without explaining them. They are flat-bottom boats, with a strong floor of plank; their dimensions are fitted to the

figure of the plan of the pier, then the work is laid in them, and their sides, as they sink, are raised a little higher than the level of the water, that the work may not be interrupted. The caisson for the first large pier of *Westminster-bridge*, wherein the late earl of *Pembroke* laid the first foundation-stone, was reckoned to contain above 150 load of timber, and exceed in tonnage a man of war of forty guns.

(Fig. 14.) IN very bad bottoms the interval of the piers is occupied by a reversed arch, so that the bridge is built upon a causeway. See the figure.

To conclude, architects have made very needless expences in making the foundations of most edifices too deep, not considering that this contributes nothing to the solidity of the building. For of two things, one, either the bottom is good or bad: if good, then the building may be raised on it with all safety: if bad, one  
should



should have recourse to a broad thick platform and gratings, without digging to seek for a more solid earth, when it may turn out worse, especially if the nature of it is very loose and moveable, in which case piling must then be used. How does that noble fabrick, the Stadthouse at *Amsterdam*, stand secure? The cathedral at *Paris*, and the bridges of that city, have very little depth of foundations. Therefore, as *M. Belidor* observes, the whole is to have firm bases; and where it is not naturally found, recourse must be had to the expedients just mentioned; and let all attention be given, that all the elevations of a building be carried up equally, and with equal good workmanship and materials.

## S E C T. XII.

*Of the wooden cintres, and of materials.*

**T**HE cintres are timber scaffoldings, made to turn the voussiors of the arches upon, and to support them in their different positions, according to the progress of the work.

CINTRES require other scaffolding to support and fix them steady in their respective situations.

THE requisite conditions of a cintre are, that by construction its strength exceeds the weight it is to bear; and all its pieces should compose one entire frame, to support equally in all its points the weight to be laid upon it, each part according to its direction and dimension.

THE two figures we have described will give an idea of the disposition of the timbers,

bers, the one for a semicircular arch, the other for a scheme arch. (Fig. 15 and 16.)

IN this place may be inserted a table of the breadths and thickneses of timber-beams, according to their different lengths, increasing by three feet, from 12 to 42 feet.

Length.—Breadth. — Thickness.

|         |            |    |            |
|---------|------------|----|------------|
| 12 feet | 10 inches, | by | 12 inches. |
| 15 — —  | 11 — —     | —  | 13         |
| 18 — —  | 12 — —     | —  | 15         |
| 21 — —  | 13 — —     | —  | 16         |
| 24 — —  | 14 — —     | —  | 18         |
| 27 — —  | 15 — —     | —  | 19         |
| 30 — —  | 16 — —     | —  | 21         |
| 33 — —  | 17 — —     | —  | 22         |
| 36 — —  | 18 — —     | —  | 23         |
| 39 — —  | 19 — —     | —  | 24         |
| 42 — —  | 20 — —     | —  | 25         |

THE manner of taking down the centres of a bridge, demands all the atten-

tion of him by whose inspection the work has been brought to its last period. Then will he be able to notice many failures as yet imperceptible.

THE cintres cannot be taken to pieces without first loosening them; and they should not be loosened but by little and little, removing some of the pins, blocks, and wedges that bind them. The reason why this is to be done so gradually, is, that the arch bearing upon the center may settle itself equably in every part.

A cintre is to be left some time under the work, to see if the arch makes any effort under the weight it bears, and offers to draw to the cintre; any damage at the key-stone should now be repaired, which from time to time must be carefully verified.

WHEN at last it is found that the voussairs have made their utmost efforts, the whole



whole cintre is then unpinned, the planks which formed its convex surface are carried away, afterwards the pieces which made up its curvature, with the braces, punchins, &c.

WHATEVER piles remain with their ends fixed in the bottom of the river, which served for the scaffolding to the cintres, are either to be sawed off very low under water, or drawn up; to do the latter, their heads are bored through large enough to admit a small cable to be introduced, which after is twisted upon a handspike, and then the pile must be forced round its point, this loosens it in the ground; the pile is drawn, pulled upwards by a purchase from two boats, the one to act on one side, and the second on the other.

ALL these precautions are hinted as indispensable; by not taking heed to them, it may sometimes prove of bad consequences, as when by suddenly and rashly  
5 taking

taking away the cintres of a great arch, before it is entirely settled, one perceives it working every moment by the gaps and shatters in the vouffoirs, which soon are unable to support the weight of the work, it then must inevitably fall into the river; there the materials perish, and oftentimes obstruct the navigation. M. \* *Gautier* avers to have seen the like misfortune happen to very considerable bridges, which might have been avoided, if the above given maxims had been followed, as at the bridge at *Coursan* in *Languedoc* (whose great arch was between seventy and eighty feet) whither he was sent by the states of the province to remedy that accident; by his advice it was repaired, and the work has remained durable and solid.

(Fig. 17.) THIS represents the most simple engine for driving piles; it will do in shallow waters, and for the lesser sort of piles. I have by me the sketch of one worked

\* *Traité des ponts*, p. 80.

worked by four men, with a spindle, and drum, spring-tongs, &c. to let fall the ram and take it up again, upon the same principles as that which served for *Westminster-bridge*; to this I object, for its being worked by horses. The drawing I mention, is of one made at *Verona*, and was used in the year 1746 to drive the piles in repairing the dykes of the river *Adige*. The perpendicular height of its two guide-posts, from the patten, is about thirty-five feet.

LET us give an explanation of the engine, as described in the figure.

*a.* The sole or patten. *b.* The cross piece, with horizontal braces. *c.* The two upright guides to, *d.* The ram. *e.* The side braces to the uprights. *f.* The back-stay, with the the ladder-stales. *g.* The prop. *h.* The pullies. *i.* The ropes.—The ends of the main ropes are divided into as many smaller, as there are required men to work the ram.

ONE word about the materials. Whatever these are, whether of hewn stone, or of brick, they should be exposed in parcels a whole year to the weather, in order to reject such as during that time are not of good proof against the heat of summer, and the frost of winter : too much precaution cannot be taken to try their goodness when not already known, in works of the least consequence.

THE quality of the earth to make bricks of, and their being well burnt, are two very essential points ; the excellency of the lime must be looked to, and that the mortar be made fine and good, that the work may take quick hold, and bind well together.

THE hardest materials make the strongest buildings, all dimensions equal ; therefore every article that can contribute to the beauty and solidity of an edifice, should be minutely examined, that whatever it  
may



may be that is intended for publick utility and ornament, may be so executed as to remain permanent, to the advantage and admiration of posterity.

I cannot finish this essay better than by a few lines to the purpose from Sir *H. Wotton*.

“ Now concerning the material part ;  
“ although surely it cannot disgrace an  
“ architect, which doth so well become  
“ a philosopher, to look into the proper-  
“ ties of stone or wood : as that firr-trees,  
“ cypresses, cedars, and such other aerial  
“ aspiring plants, being by a kind of na-  
“ tural rigour (which in man I would  
“ call pride) inflexible downwards, are  
“ thereby fittest for posts or pillars, or  
“ such upright use : that on the other  
“ side, oak, and the like true hearty tim-  
“ ber, being strong in all positions, may be  
“ better trusted in cross and traverse work,  
“ for summers, or girding, or binding-  
“ beams,

“ beams, as they term them. And so  
“ likewise to observe of stone, that some  
“ are better within, and other to bear  
“ weather ; nay to descend lower, to exa-  
“ mine sand, lime, and clay (of all which  
“ things *Vitruvius* hath discoursed with-  
“ out any daintiness, and the most of new  
“ writers) ; I say, though the speculative  
“ part of such knowledge be liberal, yet  
“ to redeem this profession, and my pre-  
“ sent pains, from indignity, I must here  
“ remember, that to chuse and sort the  
“ materials for every part of the fabrick,  
“ is a duty more proper to a second super-  
“ intendant over all the under artizans,  
“ called, as I take it by our author, *Offi-*  
“ *cinator*, lib. VI. c. 11. and in that ex-  
“ pressly distinguished from the architect,  
“ whose glory doth more consist in the  
“ designment and idea of the whole work ;  
“ and his truest ambition should be to make  
“ the FORM triumph over the MATTER :  
“ whereof I cannot but mention, by the  
“ way, a foreign pattern, namely, the  
“ church

“ church of *S. Giustina* in *Padua*; in  
“ truth, a sound piece of good art, where  
“ the materials being but ordinary stone,  
“ without any garnishment of sculpture,  
“ do yet ravish the beholder (and he  
“ knows not how) by a secret harmony  
“ in the proportions. And this indeed  
“ is that end, at which, in some degree,  
“ we should aim even in the privatest  
“ works.”

A P.

## A P P E N D I X.

**T**O make this little piece more acceptable to those who delight in the study of architecture, I have designed a few decorations \* of elevations; to which I have

\* It is far from being improper to advance, on the subject of decoration, that for greater variety, and to preserve the true antique purity and elegance of design, a review of ancient medals is no less useful to the studious architect, than to him who in a different light seeks by their means to disembroil and illustrate historical facts. — I am happy to find this opinion so well supported. You here see (says *Addison*) the copies of such ports and triumphal arches, as there are not the least traces of in the places where they once stood. You have here the models of several ancient temples, though the temples themselves, and the gods that were worshipped in them, are perished many hundred years ago. Or if there are still any foundations or ruins of former edifices, you may learn from coins what was their architecture when they stood whole and entire. These are buildings which the *Goths* and *Vandals* could not demolish, that are infinitely more durable



have added, upon the same scale, the center arch of *Westminster-bridge*. It is by comparing any invention with some approved work already executed, that we can

durable than stone or marble, and will perhaps last as long as the earth itself; they are in short so many real monuments of brass.

I have selected the four following as apposite to the present subject, and I must not omit to give some account of them for the satisfaction of the curious Reader.



can form in our minds a more perfect notion of the effects of its composition ; indeed, I had once thoughts of giving the designs of the most noted bridges in *Europe*,

FIGURE I. The reverse of a medal taken from *Goltzius de re nummaria, Tom. I. Tab. 221.*

It represents an ancient *Roman* bridge, in the *Cisalpine Gaul*, of two arches only, with columns at each butment and at the intervening pier ; at each side is a tower with steps to ascend to the passage over the bridge. This construction makes me readily imagine that it was erected as a fort, and not merely as a place of free publick transit. The pier being in the middle of the river, contrary to the common rules of art, might in this case have been so contrived on purpose, that no barks might have passage upon the stream but within reach of being destroyed from either one or the other of the towers, if they ventured to approach with any evil design.

FIGURE II. This is also from *Goltzius, Tom. II. Numismata Aug. Cæsaris, Tab. 46.*

There are three others in the same series with triumphal arches upon the bridges. The subject of the four, as their inscriptions declare, is the reparation and good order of the highways, *quod viæ munitæ sunt*. Under this article was included the building of bridges.

rope, but to execute a work of this nature with any suitable degree of correctness and elegance in the plates, would require a considerable and certain encouragement.

I

bridges. *Dion lib. LIII. cum videret Augustus vias extra urbem aliquam diu neglectas, difficilia itinera exhibere, reliquas Patrum quibusdam propriis sumptibus reficiendas mandavit. Flaminiam, quoniam eo ducturus erat exercitum ipse procuravit; estque ea statim instaurata, ac ob id, statuæ Augusti sunt supra aras in ponte Tiberis & Arimini positæ, reliquæ viæ posteriori tempori refectæ, sive publicis, sive ipsius Augusti sumptibus, hoc factum quis dicere velit, neque enim quid inter hujus & publicum ærarium intersit, satis video.*

The architecture of the superstructure in this medal is the lightest of any. Two trophies are elevated about the center. Adjacent to these, but much lower, are two triumphal arches, whose archivolts terminate upon columns, leaving a void space between them, and the greater columns at the angles. The equestrian statues at the top make an airy and complete finishing to the order.

FIGURE III. To be found in *Numismata ærea imperat.*  
*J. Vaillant.*

It is the reverse of a medal, with the head of *Augustus*. The learned antiquary who has published it,

I was informed of the new intended bridge across the *Thames*, between *London* and *Westminster-bridge*, in the spring 1753, just as I was going to embark at *Naples*, in a trip to the *Archipelago*, *Greece*, and some other parts of the *Levant*. The grand remains of *Rome* only raised in me

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gives us this account — *Augustus coloniâ Buthrotum deducit pontem ad urbis commoditatem in Ambracio sinu super Acherontem structura insigni fecit, cujus meminit PLINIUS lib. 4. cap. 1. Colonia Buthrotum maximeque nobilitatus Ambracius sinus, D. pass. faucibus spatiosum æquor accipiens, longitudinis XXXIX. M. pass. in eum defertur amnis Acheron e lacu Thesprotiæ Acherusia profuens XXXVI. M. pass. inde, & M. pedum ponte mirabilis omnia sua mirantibus.*—*Buthrotii beneficii memores pontis figuram in Augusti nummis ad æternum rei monumentum celarunt.*

To consider this medal in point of architecture, we may observe a portico of equal intercolumnations, aræostyle, to the number of five, raised to spread on each side from the center of the bridge. From this distance of the columns, I should judge it to be of the *Dorick* order. This with the beautiful proportions and symmetry of the other parts, might indeed make it a work worthy of the admiration of the beholders.

FIGURE



a stronger desire to see the charming, yet more deplorable ruins at *Athens*; more deplorable, as they daily suffer horrid devastation from the blind and stupid zeal of the *Turks*: a few years longer, and these *Barbarians* will scarce leave any traces worthy a traveller's notice. It was in this excursion that I composed the first sketches of a bridge, upon the same breadth and depth of water as that at *Westminster*, which I imagined was nearly enough a-

G 3

dapted

FIGURE IV. The type of this coin is taken from *Havercampi, Nummophylacium Reginae Christianae, Tab. 63.*

It is given as the reverse to a medal of *Septimius Severus*, supposed to have been struck on the occasion of his building some fine bridge.

What is observable, are the towers at the extremities, whose summits are either adorned with statues, or supposed to be manned with soldiers. Below these in pannels, at the sides of the towers, are represented festoons of flowers. In the water is delineated a boat or bark, (the same is in the first figure;) these are added in all probability to strike our minds with the notion of the rivers being of some consequence, and navigable.

dapted for the design in general.—Nor have I since ever had any other observations of the spot.

I found myself absolutely obliged to exclude the semicircular arch, from the shallowness of the bed of the river, and of its banks. I therefore fixed either upon an arch whose height was little more than one fourth of its aperture, or upon one whose height to its extent was as two to fix. The latter I cause to spring from the low-water mark, the former from the high-water level. This point however is not precisely determinable, without having before one the exact section of the river, with the profile of the two shores, &c. Let us hasten to an explanation of the following decorations.

Fig. I.

A design the least ornamented of any, as to the arch and its fillings. At the interval of two arches I have designed a projection

jection of large blocks of free-stone, and in the upper part a table ; on this the sculptor might exercise his art in the execution of a bas-relief.

JUST above the angular projection of the pier is a circular vacuity, called by some authors the eyes of a bridge, there are such at the beautiful bridge of *Thoulouse*. They are chiefly intended for bridges over rapid rivers, liable at times to inundations, as they facilitate the passage of the waters on such occasions. Sometimes these are circular, at other times described like niches, hollowed thorough the full breadth of the bridge, as at *Pont S. Esprit*.

Fig. II.

A second elevation decorated in a *Rustick* taste. The *Rustick* is no innovation of the moderns, there are examples of it from antiquity ; among others I saw it in the ruins of the theatre of *Bacchus* at

\* *Athens*. One very necessary caution in the use of it, is to adapt it properly, and not to *charge* any parts, especially columns, unmercifully with it. The palace *Pitti* at *Florence* is too much so; on this account it has all the air of a prison or an arsenal, rather than of a princely habitation.

Fig. III.

A decoration of a more *svelt* and airy aspect. All the exterior work for such a design should be of very fine hard stone, that the several mouldings of the cornice, pilasters and archivolt might be cut with sharp profiles; for without this attention in the workmanship of the materials, the beauty and intention of such a design is lost.

Fig. IV.

ANOTHER design of *Rustick* ornament for its archivolt, with niches in the intermediate

\* Pausanius, Wheeler, Spon, Fanelli, *Antiquities of Athens*, &c.



diate spaces of two arches. The niches are crowned with pediments of *Tuscan* distribution, and bordered with *Rustick* vermiculated quoins.

Fig. V.

REPRESENTS a design which I composed for my elevation of the new-projected bridge. The arch is ornamented with radiated bands, and all the vouffoirs in the fillings of the arch prolonged in the same direction taken from the center. — This method is happily executed at *Westminster-bridge*. The intervals between the bands is in sesqui-alterate proportion of their breadths. On each side the arch is a tabernacle modulated after the *Dorick* ordinance. The columns without bases ; they stand upon a projected plinth. In that part of the balustrade over the tabernacles, is a recess crowned with a circular pediment, for the same conveniency and shelter of foot-passengers as the turrets at *Westminster-bridge*. In all these designs, I

consider the height of the balustrade must be in full proportion with every other part of the arch, the safety of the passage requires it, as well as the rules of symmetry.

Fig. VI.

THE center arch of *Westminster-bridge* taken from an authentick design. This decoration affords a very beautiful symmetry. The \* modiglions of the cornice are modelled upon those of the second exterior cornice of the *Rotunda* at *Rome*. It were to be wished, that the ascent from the

\* *Palladio* has not decorated one of his stone-bridges without modiglions. A short-sighted connoisseur, considers them only as belonging to the roof of an edifice, where they are designed to represent the ends of the rafters; but are there no flat roofs, and then may they not with as much propriety represent the ends of the joists?

*Sopra queste, sono poste altre travi per traverso, le quali fanno il piano o suolo del ponte, e sportano con le loro teste al quanto fuori del rimanente del opera, paiono i modiglioni di una cornice.*

Palladio del ponte di Bassano.

the ends to the center of this fine bridge had been made less, for by this declivity the objects vanish at about half way, and the mind tires with the notion of continually ascending. Both for the sake of conveniency and beauty, the road over a bridge should be as level as possible; and if any ascent is requisite, it should be something more sudden, and taken at one or both extremities; the bridge at *Rimini* has this ascent only at part of one of the extreme arches.

THE length of *Westminster-bridge* is equal to about two fifths of the *Mall* in *St. James's Park* (or 1223 *English Feet*): how delightful would it be to have an uninterrupted *vista* this whole extent?

IN cities exposed to the frequent vicissitudes of war and peace, the command of a bridge from one extremity to the other is an essential consideration, as it may prevent any lodgement being made  
upon

upon it, without having recourse to the sad necessity of breaking it down; for when that happens, in a few hours may be ruined what has been a subject of great labour and expence for several years.

I have been persuaded to add an elevation of my design for a bridge; it was delivered by a friend of mine to a person of eminence in the city, since deceased; but I have reason to believe, that it was by him at once condemned to the obscurity of some dark corner: since that, it has been offered to another magistrate; this, as it came anonymously, and too late, has passed unnoticed, and I have only, within these few days, had it returned. It would have piqued me too sensibly to have had the production of some years study and expence, gone off in the blaze of the best *Virginia*.

THE draught I here give (Plate IV.) I have reduced to the same scale as that published



lished in the *London Magazine* for *March last*, on assurance that it is authentick and published by consent of Mr. *Mylne*. I have not the advantage to know this gentleman; yet from the character he bears as an artist I wish him all the success his rising merit deserves. But, as in matters of art and science, every human production is liable to fallibility, to point out faults must not be construed into a spirit of detraction, when it is done with a mere view to strike at error, and for the readier advancement to all the perfection that the subject will admit of.

I shall therefore take the liberty to observe as follows of Mr. *Mylne's* design. The decoration, as there intended, is void of that eurythmy which affords the *venusta species ædificii*; for there is a horrible disproportion between the columns and the recesses which they are intended to support, which is rendered more striking by the *littleness* of the pediments. Such a  
dis-

distribution has all the air of those *Lapland* huts, supported upon the trunks of one or two tall firrs, wherein the people of that country are said to keep their provisions secure from the insults of bears and other wild beasts. As to the columns being detached, it would have been preferable to have taken the requisite projection of the pier for support to the recesses above, and to have made the columns only in a part of their diameters, faillant from the wall. The side views of these columns will serve no other purposes than for the watermens boys to play at *bo-peep*. I am fully convinced that there is an error to be continually sinking the diameters of columns, whether square or round, into the thicknesses of walls, and by these means giving all the air and effect only of a painted scene to an elevation, so that in many cases they might all be shaved off without detriment, nay, many times with advantage, when injudiciously designed without taste and judgment.

AN-

ANOTHER grand disproportion of these columns is with respect to the statues supposed to be placed between them. For though a statue placed on the summit of a column, with its entablature, is made in much smaller proportion than these are supposed to be, there its elevated situation gives it an air of dignity; but where the proportion of columns so greatly exceeds that of a niche suitable to the intended statue, the oppressed figure (unless of the size of the *Colossus* of *Rhodes*) has all its significancy overwhelmed in so disadvantageous a situation.

I cannot apprehend there can be any construction of the materials to render an elliptical arch of equal strength to a semicircular, or portion of a circle of the same base and height. I am inclined to give a plain geometrical state of the case, wherein the materials are disposed in the usual radiated manner, and by this let any one judge.

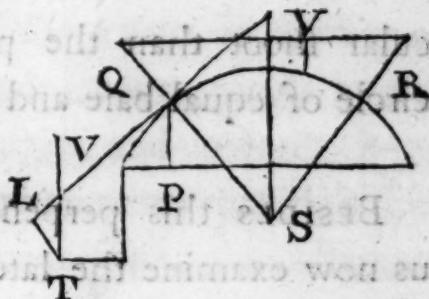
CON-







Now in this other figure, if one looks upon SQYR, it will be found that the angle QSR



is by several degrees not so acute as ABC, the wedge therefore, therein considered, will have less power to drive off the two piers, and the parts of the arch below Q and R, than in the former figure, where the angle of the supposed wedge is so much more acute. And if the line QS is considered as an inclined plane, it must be taken for granted, that being more inclined to the horizontal, the part QY will be less disposed to descend than the part AD of the ellipsis, in the former figure; consequently all the vouffoirs, that make up the scheme arch, being taken as wedges, or as bodies tending to descend on inclined planes, will have less powers to fall than the vouffoirs of the elliptical arch. From this may be absolutely concluded, that the elliptical arch has more perpendi-

H

cular

cular shoot than the portion of a semicircle of equal base and height.

BESIDES this perpendicular shoot, let us now examine the lateral pressure of the two arches.

THE lateral drift of arches is in direction of the tangents drawn perpendicular to the radius, which in both intersects an equal portion of the arch. Now in the first figure, the tangent MD being intersected by the perpendicular KA, makes the angle MAK more obtuse than in the other figure is the angle VQP formed by the tangent VY, intersected by the perpendicular PQ. Therefore the pressure of the elliptical EAD is more lateral than the arch VQY, and the lever MF is longer than the lever LT, consequently the arch EAD requires a stronger pier than the arch VQY, being in every respect, *cæteris paribus*, weaker.

WHAT

WHAT M. Muller \* says in favour of the elliptical, that it saves materials by the vacuity at the springing and upwards, is not true in practice, when more materials than these savings are requisite to the difference of the pier of it, and of the circular arch.

THAT by this vacuity it allows a freer passage for navigation, is too trifling an argument in its favour.

THAT by this vacuity it has more gracefulness of appearance, is the same as to assert, that the leaning towers of *Pisa* or *Bologna* should serve as models for our houses and churches.

As to my design, considering the section of the river true, as laid down in the above-mentioned of M. Mylne's, for I am not otherwise informed of its foundings, I have fixed the height of my arches at something more than one fourth of their aperture. The shallowness of the river  
has

\* Treatise of practical fortification.



has determined me to make my arches spring from high - water mark. — This method takes up much less space in the breadth of water, and the shortness of the piers, with good bases and foundations, will be found able to allow of this construction, if the solidity of the materials likewise is answerable.

In a bridge of such extent, the crown of the center-arch should be marked by some distinguished notice, that the beholders may at once catch the middle of the stream and of the bridge.



F I N I S.



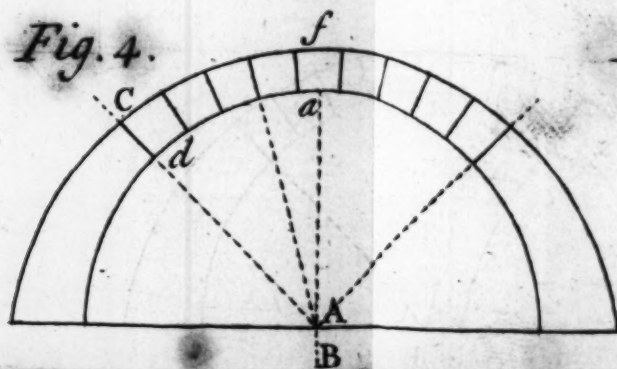
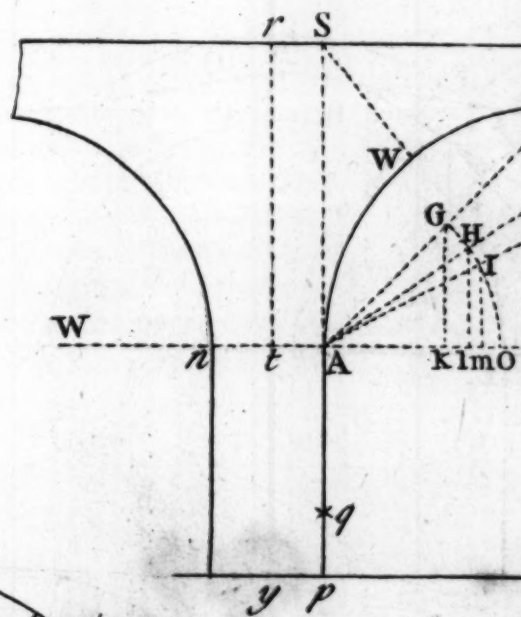
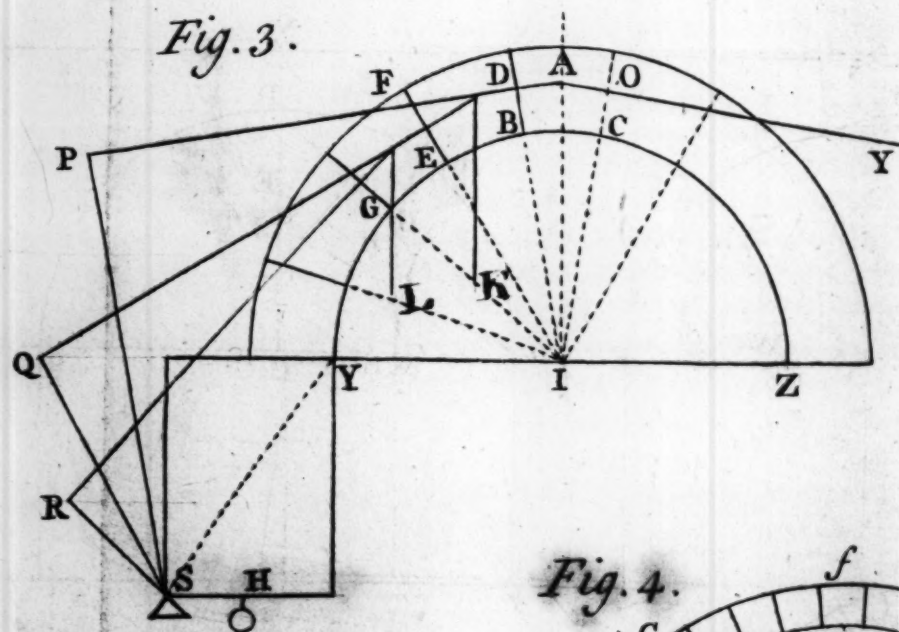
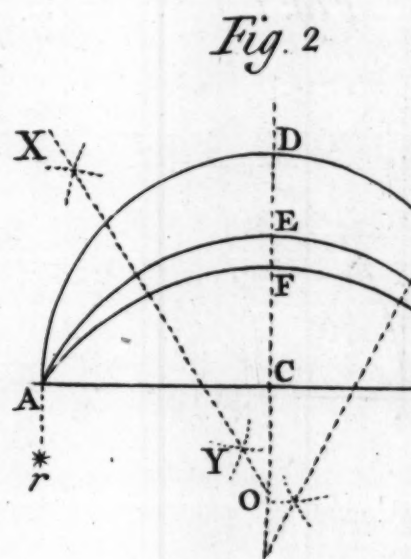
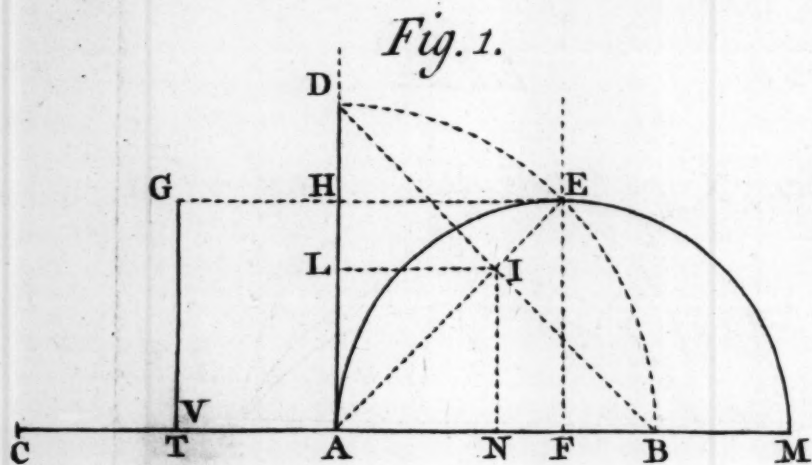


Fig. 6.

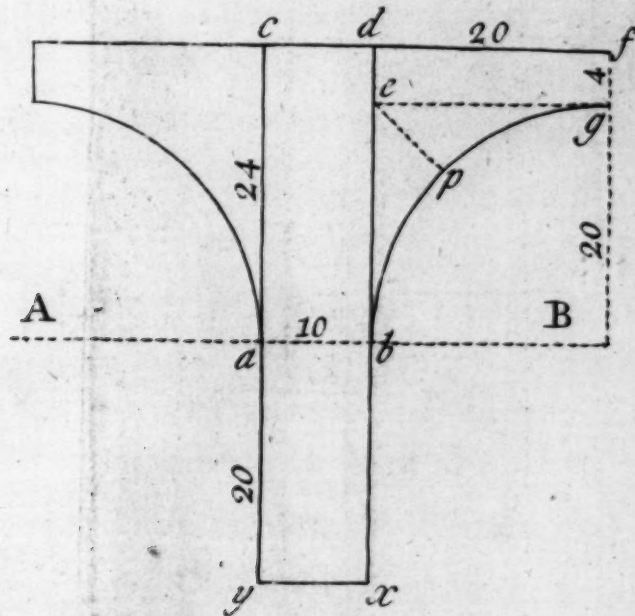


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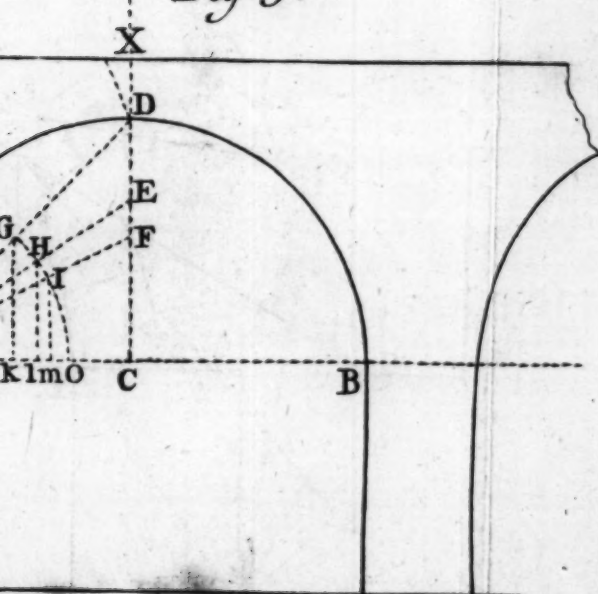


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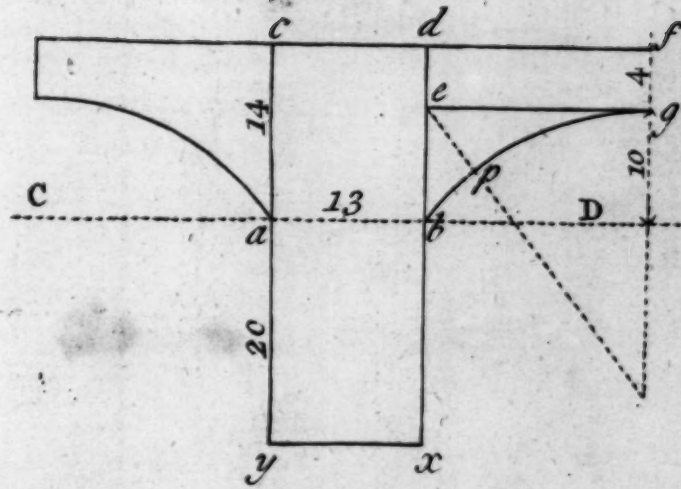


Fig. 1.



Fig. 8.

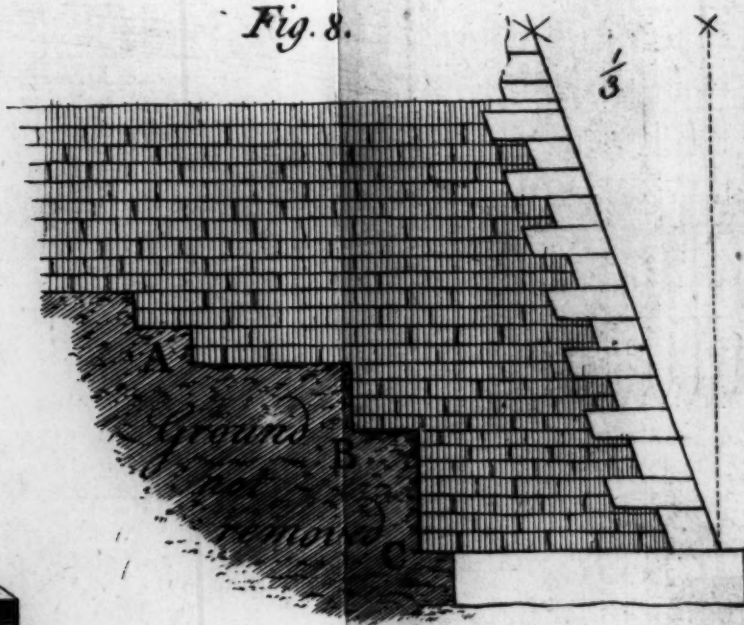


Fig. 17.

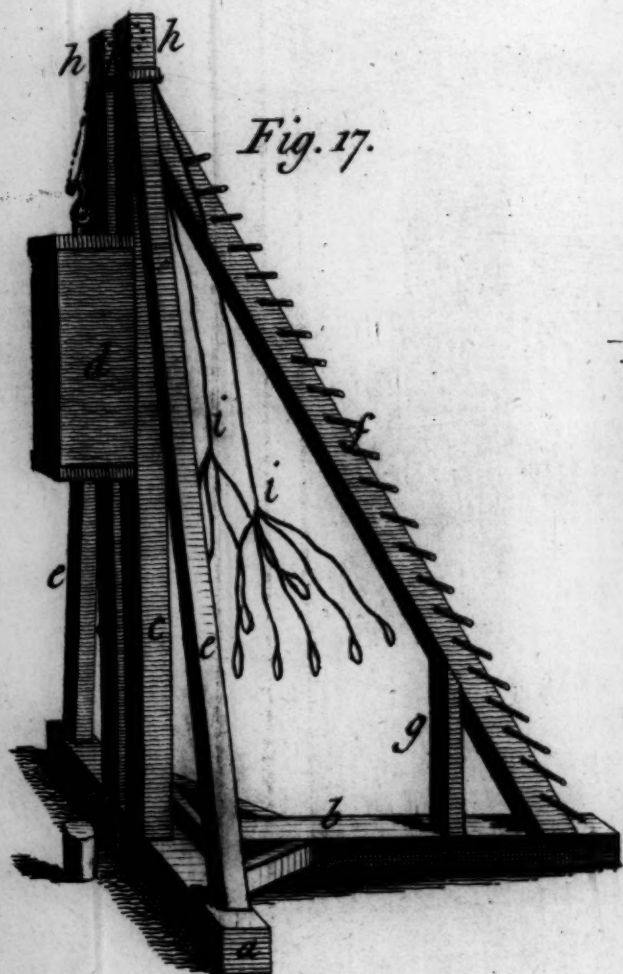


Fig. 15.

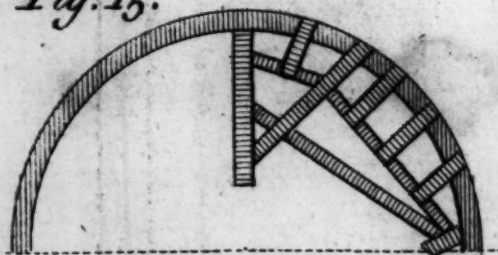


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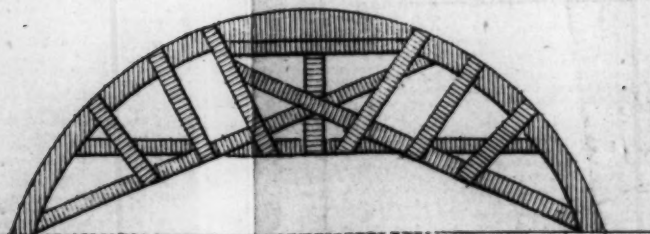




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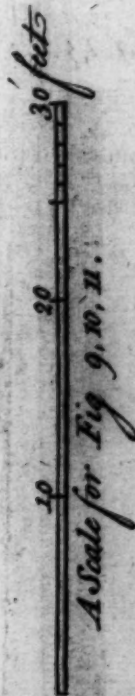
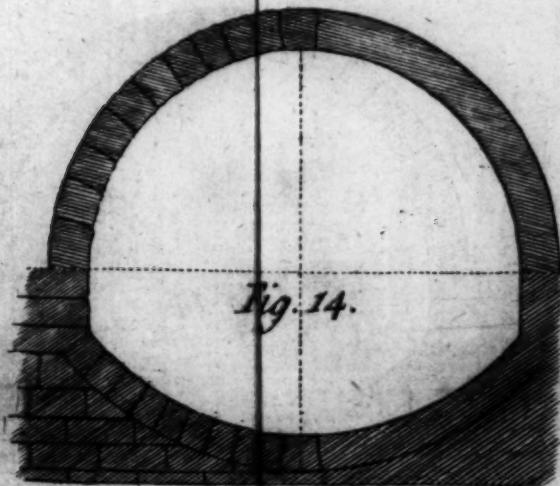
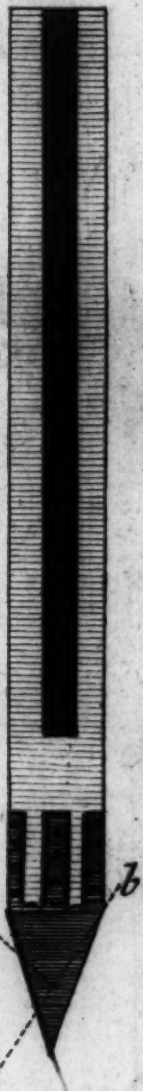


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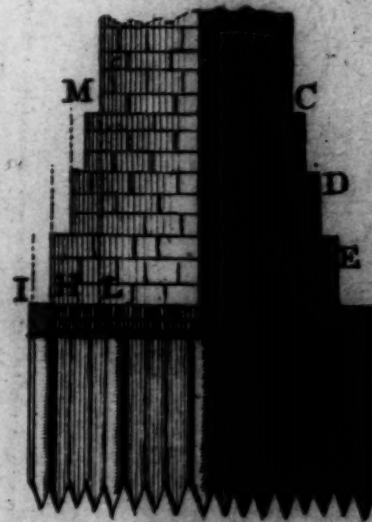


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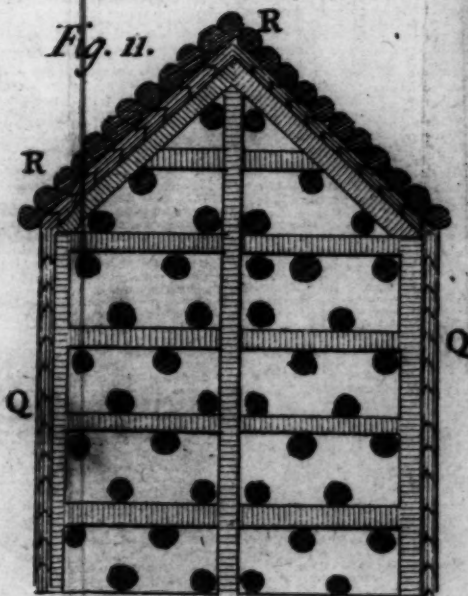


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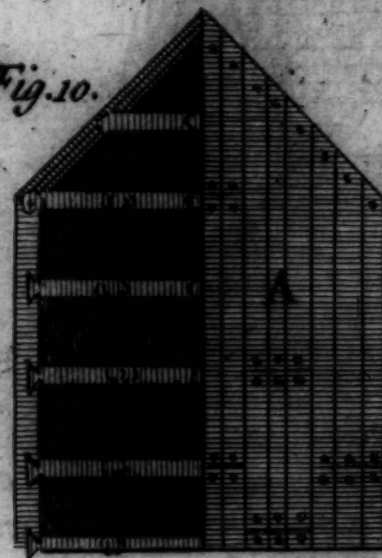
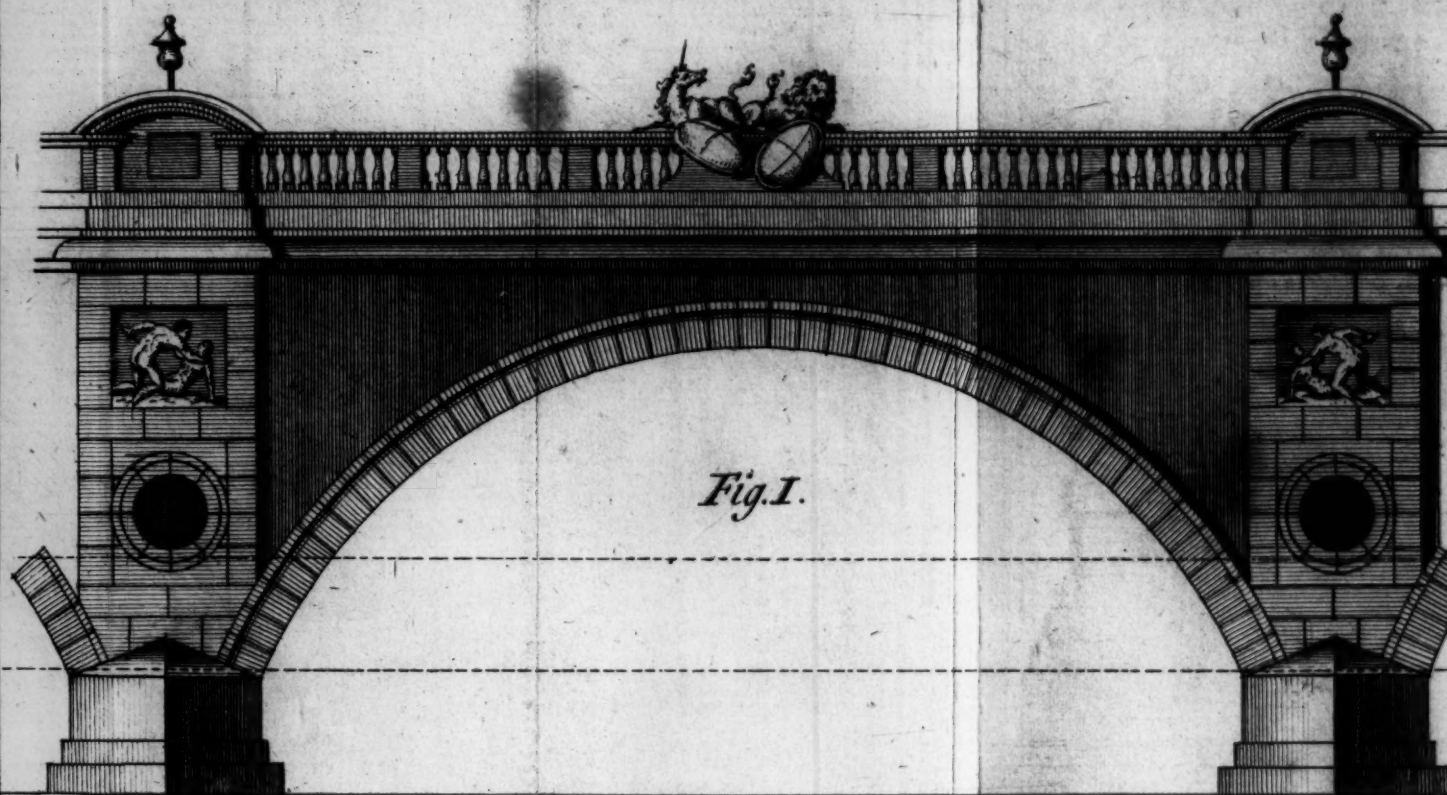
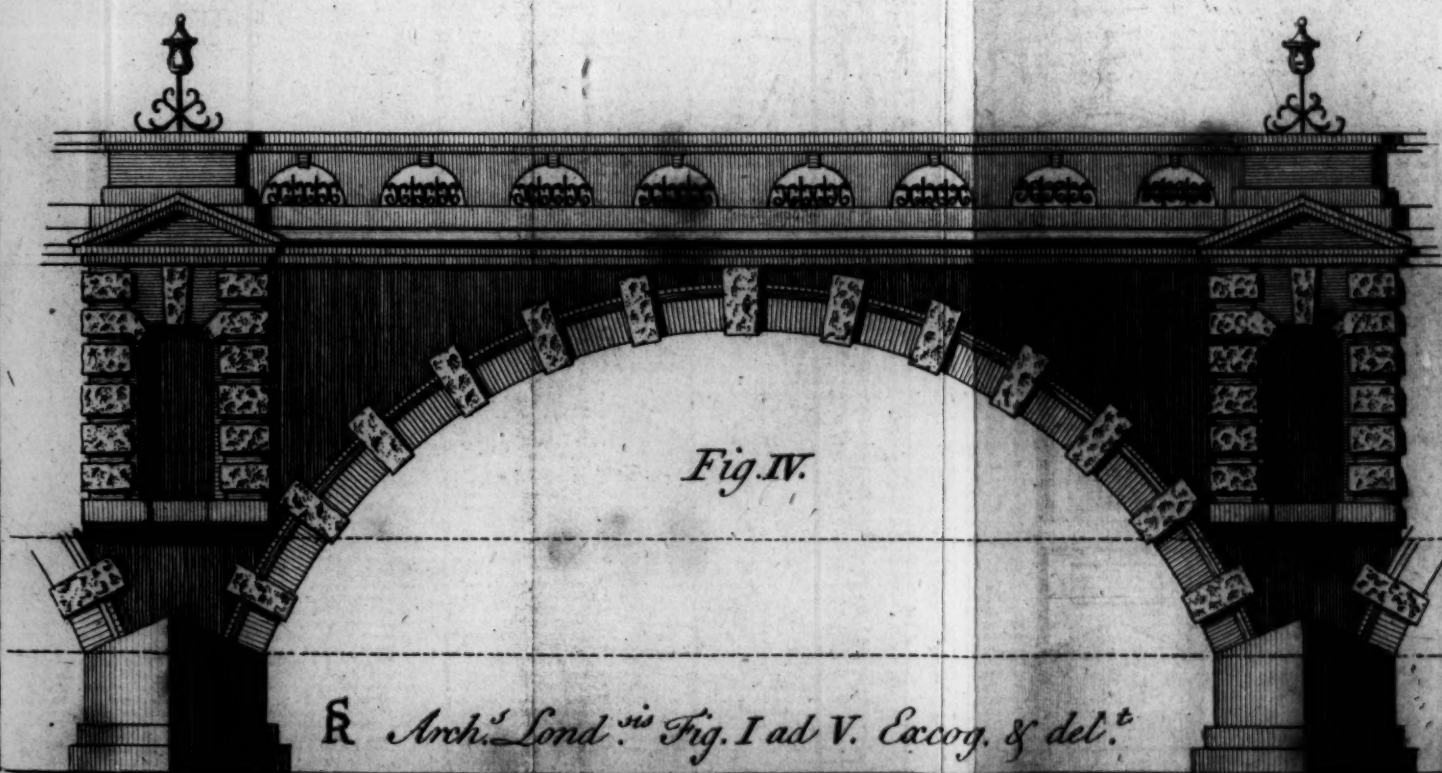


Fig. 12.



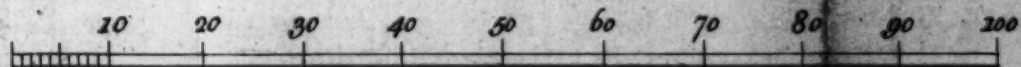
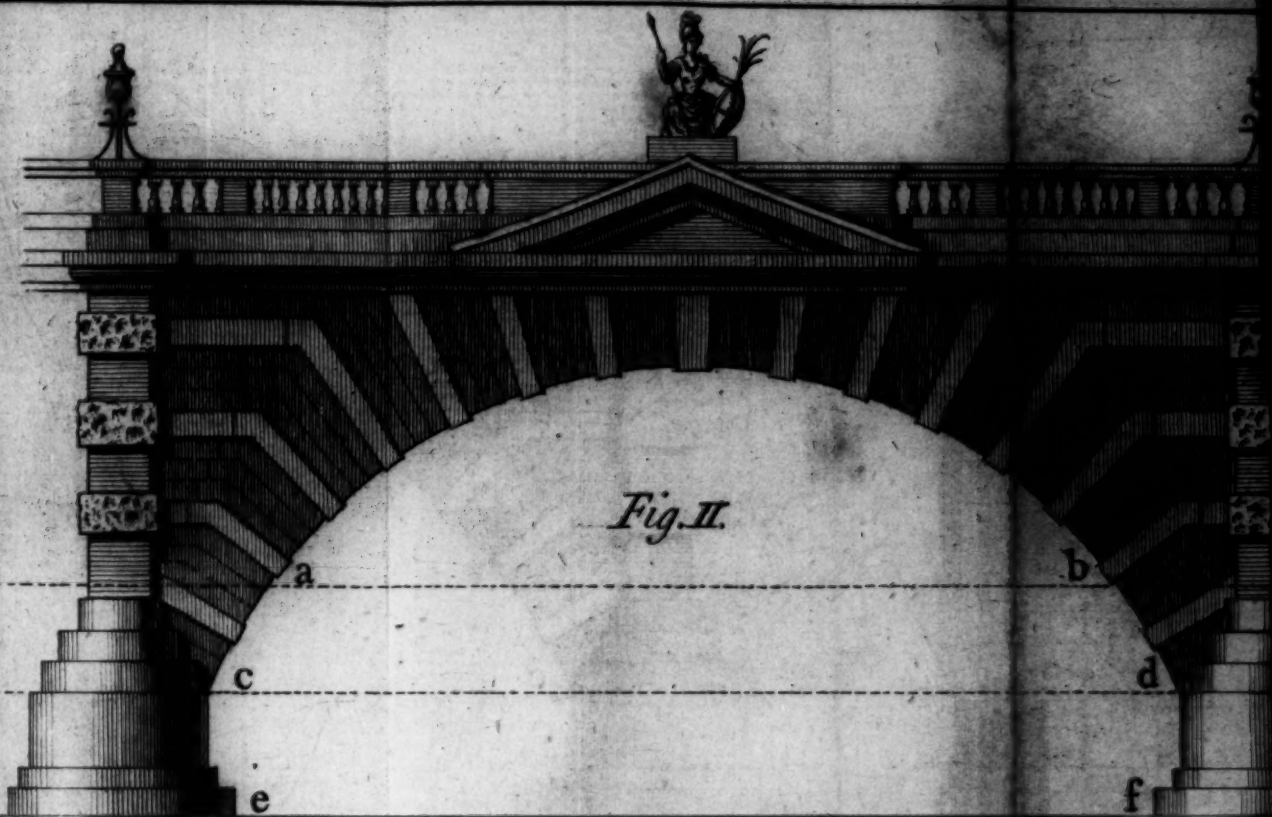


*Fig. I.*



*Fig. IV.*

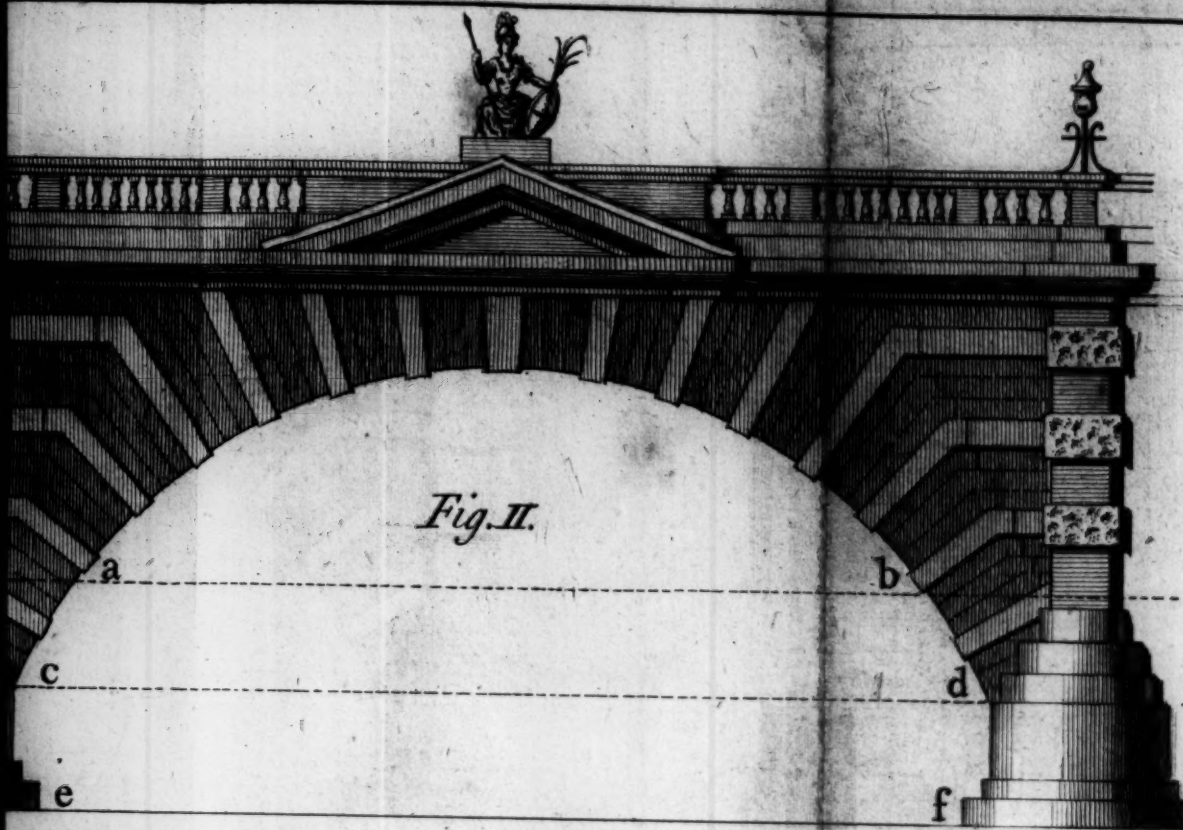
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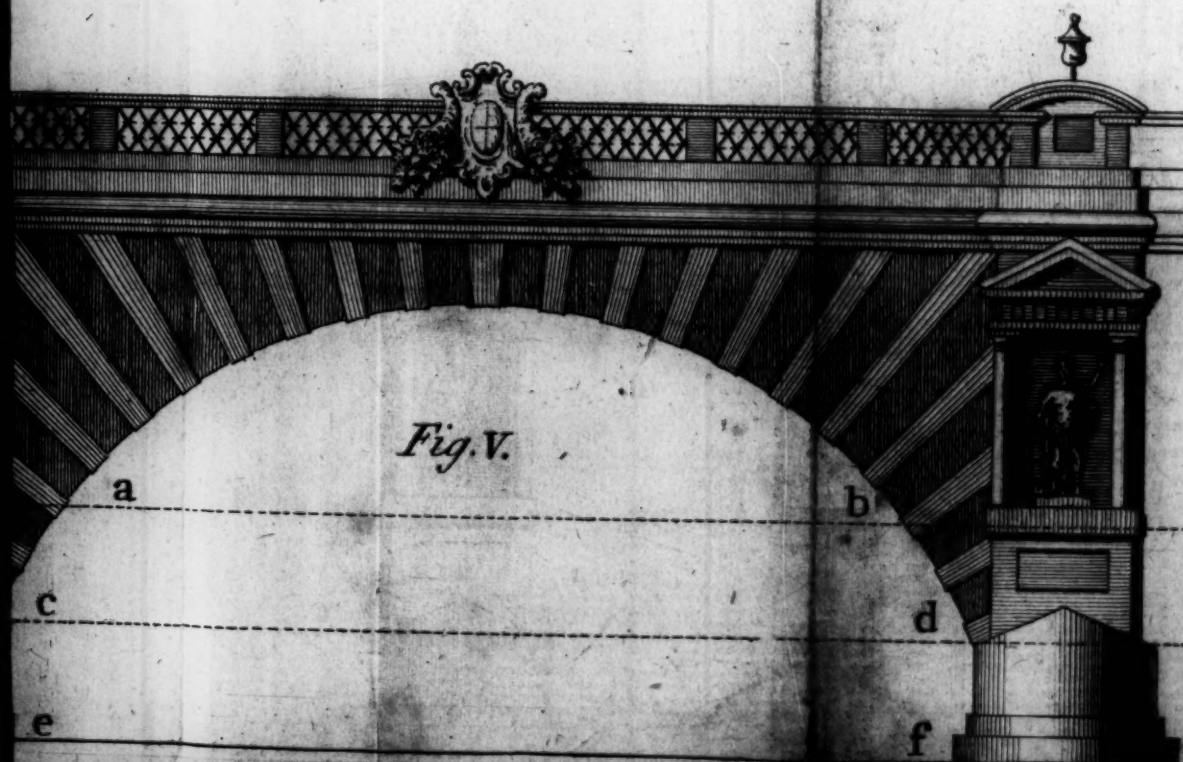
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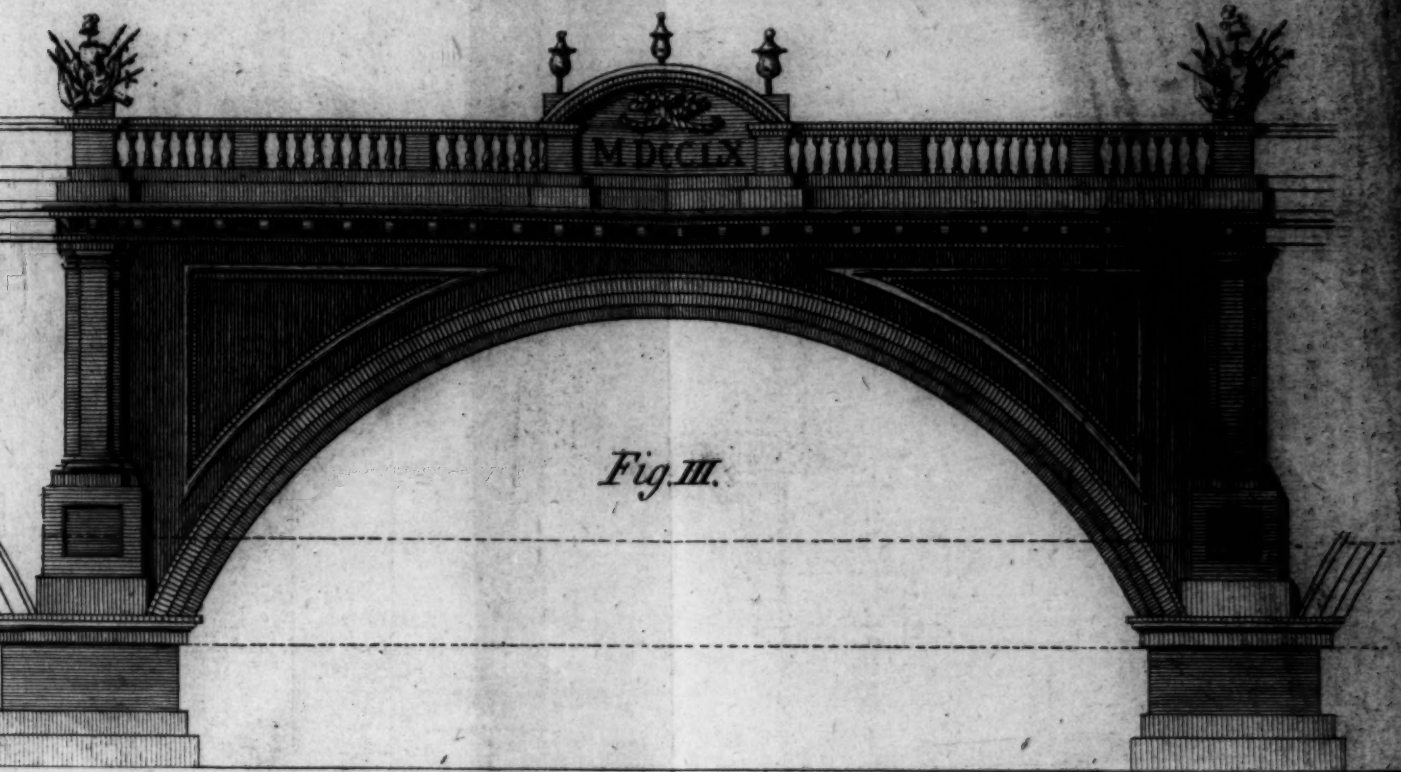






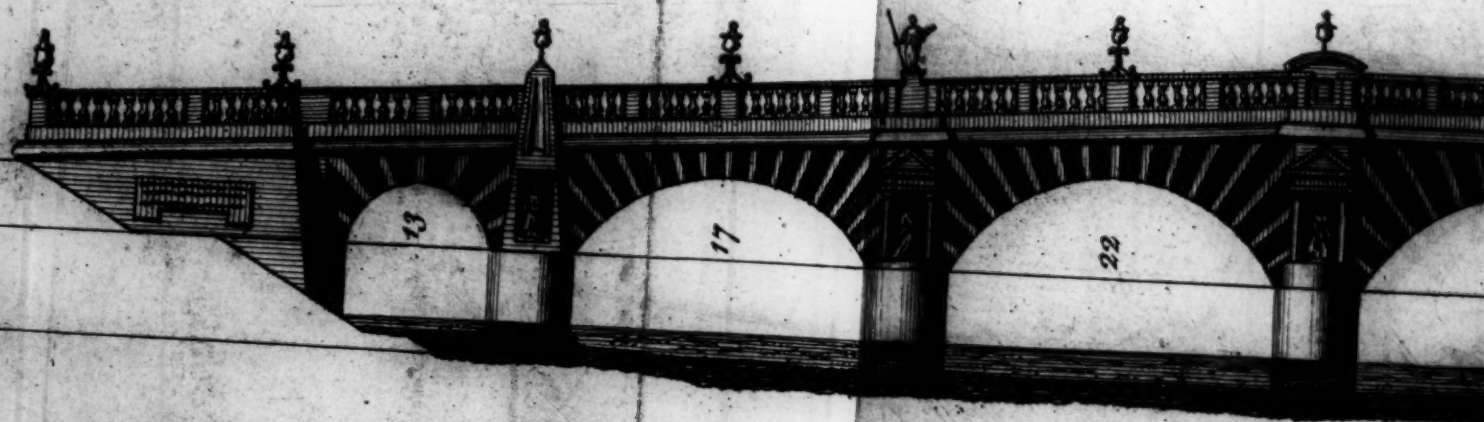
*A Scale of English Feet .*





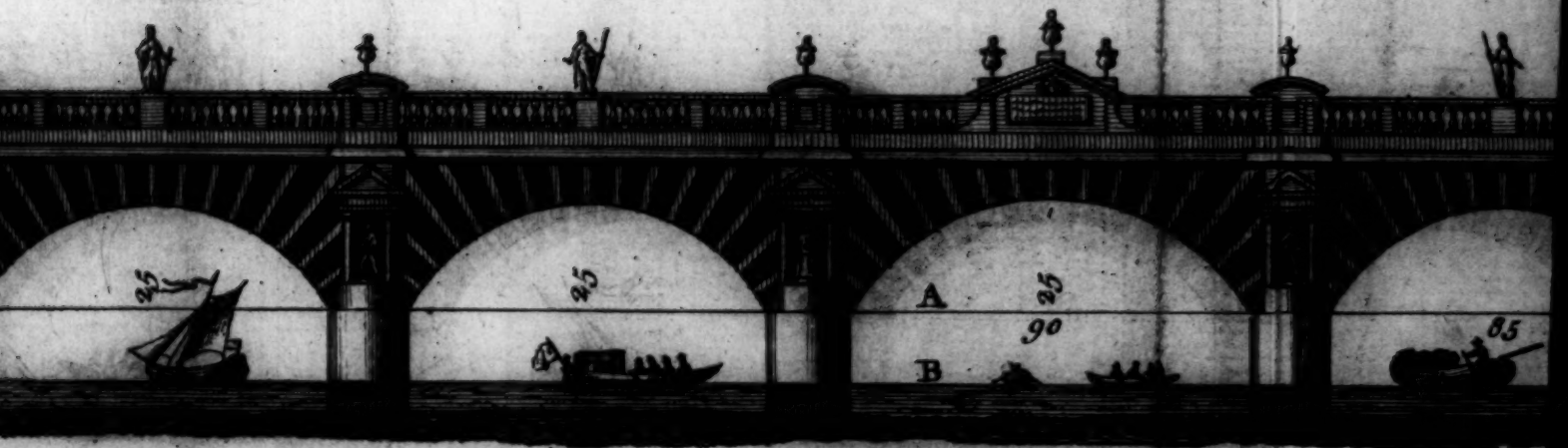


*A*



*The Scale*  
10 20 30 40 50 100

*A Geometrical Design of a STONE BRIDGE prop  
of LONDON.*

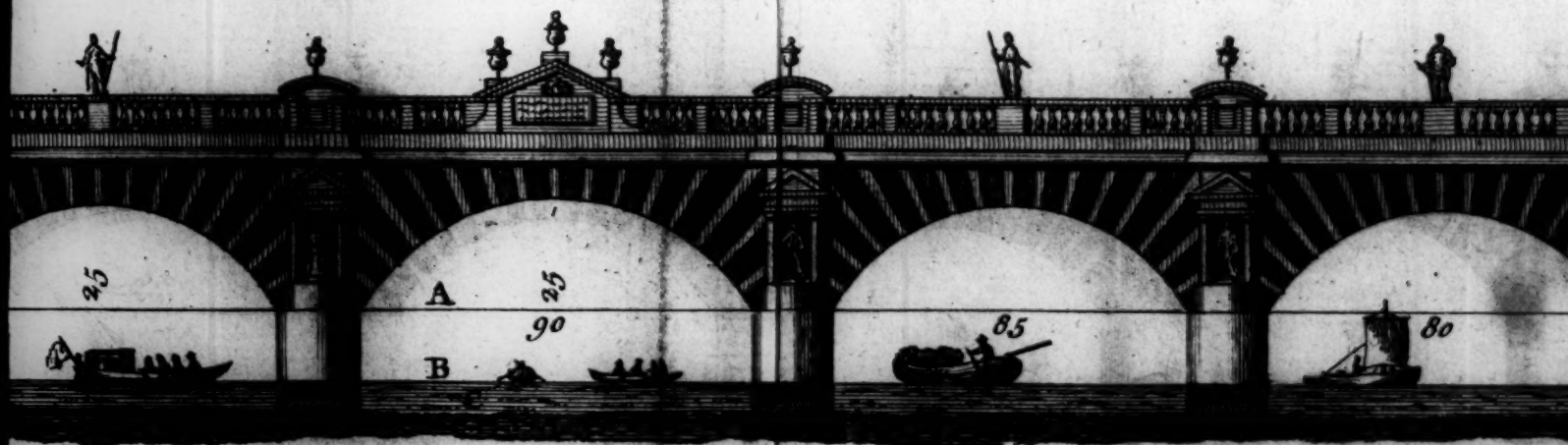


*Scale.*  
100

200 English Feet.

A. The high W  
B. The Low W  
C. An imagin  
Bed of the D  
depth of the E

*Design of a STONE BRIDGE proposed to the Corporation  
of LONDON.*



00 English Feet.

- A. *The High Water Level.*
- B. *The Low Water Level.*
- C. *An imaginary Section of the  
Bed of the River, shewing the  
depth of the Foundations.*



Pl. IV.



J. Mynde sc.